THE GLASS INDUSTRY

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ON THE SPECTRAL TRANSMISSION OF COLORED CONTAINER GLASS[1]

By DONALD E. SHARP*

Introduction

It is a matter of common knowledge, as well as of scientific observation, that many substances, including certain drugs and chemicals, undergo changes from the action of light. In some instances, as, for example, in the case of photography, these changes may be considered beneficial, while, as in the case of many drugs and chemicals, the changes may be detrimental, resulting in a loss of potency, or an alteration in taste, rendering the material less useful, or even useless, for the purposes intended.

The consideration, therefore, of a suitable container, from the standpoint of light and its effects, is an important one. Many products, including various drugs, are packed in glass containers, and it is desirable, as well as essential, to know the degree of protection from harmful light radiation that may be available in a given instance. It is sufficient merely to mention that there are penalties that apply for misbranding under the laws dealing with the labeling of drugs and other products, which may operate even where a product correctly branded when packed has subsequently deteriorated through the action of light, heat or other agency.

It is the purpose of this paper to present certain data on the spectral transmission of colored glasses and some few other materials that might be employed for protective purposes. It should be emphasized that it is not the purpose to draw conclusions as to the extent of protection offered by the various glasses studied, but rather to make public data that have not been readily available in the past on their absorptive properties.

Methods

As an approach to a study of this problem, it was necessary to determine the light absorbing properties of the colored container glasses that are now made commercially. Samples were therefore obtained of light green, emerald green, blue, and amber glass. Because among the glasses readily obtainable commercially, amber was thought to hold the most promise for light protection, an attempt was made to obtain samples of amber glass from every domestic, and some foreign manufacturers.

Measurements were made in the visible region on most of the amber glasses with a recording spectrophotometer. Measurements in the ultra-violet on these samples were made at prominent lines of the mercury spectrum utilizing a double quartz prism monochromator, and photocell and amplifier. The same equipment was used on a few of the other glasses but most of these were measured both in the visible and the near ultra-violet with a Cenco-Sheard Spectrophotelometer, a high pressure mercury arc being used as a source for the shorter wavelengths.

Suitable pieces cut from bottles were ground and polished so that their surfaces were reasonably plane and parallel. An effort was made to finish the samples to an approximate thickness of 2 mm., but, in each instance, the data were recalculated to correspond to the transmission for a 2 mm. thickness so that comparisons would be facilitated.

The accuracy of the measurements was reasonably high, probably of the order of $\pm$ 1% at the higher values, and surely within 10% of the magnitude measured for values where the transmission was 5% or below. In general, in using the Cenco-Sheard instrument, the width of the entrance slit was 1.5 mm. and the exit slit was set for 10 $m\mu$.

Transmission and Transmissivity

When a beam of radiant energy in air falls upon the surface of a plane parallel piece of transparent material such as glass, a small portion of the energy is reflected by the first surface of contact. The balance of the energy enters the glass, where part of it is absorbed, and the remainder is transmitted to the second surface where another reflection loss takes place, the residue being transmitted through the second surface. The transmission is the ratio of the balance of the energy that passes through the glass after the losses by reflection and by absorption, to the original energy.

The energy that is absorbed is the characteristic of the glass in which we are chiefly interested, and this depends on the physical and chemical nature of the material. The reflection loss depends primarily on the angle of incidence of the light and on the refractive index of the glass.

Fresnel has shown that if the normally incident energy be taken as unity, the reflection loss R from a single surface may be determined from the expression:

$$R = \left(\frac{n-1}{n+1}\right)^2$$

where n is the refractive index of the glass for the spectral region under consideration.

For a plane parallel piece of glass, where two surfaces are to be considered, the maximum transmission

[1]The content of this paper is essentially that of a thesis submitted to the New York State College of Ceramics at Alfred University, June 1, 1942, to meet in part the requirements for the Professional Degree of Ceramic Engineer.

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that would be obtainable would therefore be found by the expression:

$$T = (1 - R)^2$$

For container glass, which, on the average, has a refractive index of about 1.5, the maximum transmission would be about 92 per cent, the balance of the light, 8 per cent, being lost by reflection.

If reflection loss is ignored for the moment, and only that portion of the light transmitted by the glass is considered, it is found that the ratio of intensity of light entering the material to that leaving, depends on the thickness of the glass and its absorption coefficient. Thus if I_0 be the intensity before absorption, and I the intensity after absorption, the two are related to the thickness t and the absorption coefficient B by the expression:

$$\frac{I}{I_0} = 10^{-Bt}$$

The ratio $\frac{I}{I_0} \times 100$ is called the percentage transmittance of the glass. Taking logarithms of both sides, and designating transmittance by C, we obtain

$$\text{Log } C = -Bt$$

The transmittance of a glass for a different thickness may therefore be calculated from the known transmittance for a given thickness from

$$\text{Log } C_2 = \frac{t_2}{t_1} \log C_1$$

Where C_1 and C_2 are the transmittances and t_1 and t_2 the corresponding thicknesses.

It will be obvious, however, that reflection losses cannot be overlooked, and if these are to be taken into account, we find, since $C = T/(1-R)^2$ that

$$\text{Log } \frac{T_2}{(1-R)^2} = \frac{t_2}{t_1} \text{Log } \frac{T_1}{(1-R)^2}$$

where T_1 and T_2 are transmissions corresponding to thicknesses t_1 and t_2 respectively, and R is determined from Fresnel's expression $R = \left(\frac{n-1}{n+1}\right)^2$, the incidence of the light being assumed to be normal. (See explanation of symbols to nomenclature at end of this article.)

All glasses used for mass production of containers are, by force of circumstance, soda-lime-silica glasses whose optical properties, as regards refractive index and dispersion, fall within relatively narrow limits. Thus, in general, the refractive index of container glass may be taken to be approximately 1.5.

Moreover, in such glasses throughout the visible spectrum, say between the wavelengths 400 $m\mu$ and 750 $m\mu$ the dispersion is of the order of 0.02. The total variation in index, due both to dispersion and to variation in composition of the glass itself, is unlikely to exceed ± 0.02.

TABLE I

Refractive Index of a Container Glass for Various Parts of the Visual Spectrum

Wavelength $m\mu$	*Refractive Index*	*Transmittance* (1-*R*)-
400	1.520	0.917
450	1.514	0.918
500	1.510	0.919
550	1.507	0.920
600	1.505	0.920
650	1.503	0.921
700	1.501	0.921
750	1.500	0.922

The refractive properties of a typical container glass over the visible region of the spectrum are shown in Table I together with corresponding values of $(1-R)^2$.

It will be noted that a variation in refractive index from 1.50 to 1.52 brings about a corresponding change in $(1-R)^2$ from 0.922 to 0.917, and, therefore, for all intents and purposes, with container glasses of the type under consideration, a value of 0.92 may be utilized for all the glasses for all wavelengths throughout the spectral range, considered without introducing undue error.

This permits simplification of the equation for calculation of effect of thickness on transmission to

$$\text{Log } \frac{T_2}{0.92} = \frac{t_2}{t_1} \log \frac{T_1}{0.92}$$

Computing Transmission for Different Thicknesses

Assume that several measurements have been made on a glass of 2.0 mm. thickness, and it is desired to convert the transmission values to correspond to a 3.0 mm. thickness. Merely for convenience of illustration, assume that the transmission data are as follows:

Sample Thickness 2.0 mm.

Measurement	*Transmission*
A	15.0%
B	22.0
C	38.2
D	67.0

A customary method of procedure is to use paper

TABLE II

Conversion of transmissions to 3 mm. thickness from measurements made on 2 mm. thickness

$t_2/t_1 = 1.5$

	Measurement A	B	C	D
T_1 (2 mm. Thickness)	0.150	0.220	0.382	0.670
Log T_1 (from log tables)	9.1761—10	9.3424—10	9.5821—10	9.8261—10
	(—0.8239)	(—0.6576)	(—0.4179)	(—0.1739)
— Log .92 = (—0.0362)	—(—0.0362)	—(—0.0362)	—(—0.0362)	—(—0.0362)
	(—0.7877)	(—0.6214)	(—0.3817)	(—0.1377)
$\times \frac{t_2}{t_1}$ = (1.5)	× 1.5	× 1.5	× 1.5	× 1.5
	(—1.1817)	(—0.9321)	(—0.5726)	(—0.2066)
+ Log .92	+(—0.0362)	+(—0.0362)	+(—0.0362)	+(—0.0362)
	(—1.2179)	(—0.9683)	(—0.6088)	(—0.2428)
Log T_2	8.7821—10	9.0317—10	9.3912—10	9.7572—10
T_2 (from log tables)	0.0606	0.1076	0.2462	0.5719
% Transmission at 3 mm.	6.1	10.8	24.6	57.2

ruled vertically and follow the calculations through as shown in Table II.

This process is time-consuming even if one is accustomed to working directly with negative logarithms. The use of a slide rule for obtaining the logarithms introduces no great error, but the work is tedious, nevertheless, especially when the data for many points must be calculated as is necessary if a complete spectral transmission curve is to be converted.

A special table has been furnished by Gage[1] which greatly simplifies the calculations. This is reproduced here in Table III, and is a tabulation of transmission values and the corresponding values of Gage's expression βt.

The use of the table may best be explained by specific examples, for which the problems already worked out in Table II will be used. For example, measurement B in the previous calculations gave a transmission of 22 per cent for a 2 mm. thickness and it was desired to find the transmission for a thickness of 3 mm. The thickness ratio is therefore 1.5.

Consulting Table III, under the column headed Transmission, it is found that a transmission of 0.2200 has a corresponding value of Bt of about 0.6215. This number is multiplied by the thickness ratio 1.5, thereby obtaining the number 0.9323. Now using the values of Bt as argument, the corresponding transmission is obtained from the tables as 0.1075, and the percentage transmission is determined as being 10.75 per cent.

The construction of the table is like that of a logarithm table, but it yields negative logs directly, corrected, moreover, by the logarithm of the factor 0.92, so that the only computation necessary is the multiplication of the values of Bt by the thickness ratio.

The ease of making the calculations by use of the table is evident if the four measurements quoted previously are converted by this method. This is done in Table IV in the same general form as was used in Table II.

(*Continued on page* 353)

[1] Glass Color Filters for Special Applications, H. P. Gage, J. Opt. Soc. Am. 27, 4, 161 (1937).

TABLE III

	Transmission									
βt	9	8	7	6	5	4	3	2	1	0
99	9226	9247	9268	9290	9311	9333	9354	9376	9397	9419
98	9441	9462	9484	9506	9528	9550	9572	9594	9616	9638
97	9661	9683	9705	9727	9750	9772	9795	9817	9840	9863
96	9886	9908	9931	9954	9977	1000	1002	1005	1007	1009
95	1012	1014	1016	1019	1021	1023	1026	1028	1030	1033
94	1035	1038	1040	1042	1045	1047	1050	1052	1054	1057
93	1059	1062	1064	1067	1069	1072	1074	1076	1079	1081
92	1084	1086	1089	1091	1094	1096	1099	1102	1104	1107
91	1109	1112	1114	1117	1119	1122	1125	1127	1130	1132
90	1135	1138	1140	1143	1146	1148	1151	1153	1156	1159
89	1161	1164	1167	1169	1172	1175	1178	1180	1183	1186
88	1189	1191	1194	1197	1199	1202	1205	1208	1211	1213
87	1216	1219	1222	1225	1227	1230	1233	1236	1239	1242
86	1245	1247	1250	1253	1256	1259	1262	1265	1268	1271
85	1274	1276	1279	1282	1285	1288	1291	1294	1297	1300
84	1303	1306	1309	1312	1315	1318	1321	1324	1327	1330
83	1334	1337	1340	1343	1346	1349	1352	1355	1358	1361
82	1365	1368	1371	1374	1377	1380	1384	1387	1390	1393
81	1396	1400	1403	1406	1409	1413	1416	1419	1422	1426
80	1429	1432	1435	1439	1442	1445	1449	1452	1455	1459
79	1462	1466	1469	1472	1476	1479	1483	1486	1489	1493
78	1496	1500	1503	1507	1510	1514	1517	1521	1524	1528
77	1531	1535	1538	1542	1545	1549	1552	1556	1560	1563
76	1567	1570	1574	1578	1581	1585	1589	1592	1596	1600
75	1603	1607	1611	1614	1618	1622	1626	1629	1633	1637
74	1641	1644	1648	1652	1656	1660	1663	1667	1671	1675
73	1679	1683	1687	1690	1694	1698	1702	1706	1710	1714
72	1718	1722	1726	1730	1734	1738	1742	1746	1750	1754
71	1758	1762	1766	1770	1774	1778	1782	1786	1791	1795
70	1799	1803	1807	1811	1816	1820	1824	1828	1832	1837
69	1841	1845	1849	1854	1858	1862	1866	1871	1875	1879
68	1884	1888	1892	1897	1901	1905	1910	1914	1919	1923
67	1928	1932	1936	1941	1945	1950	1954	1959	1963	1968
66	1972	1977	1982	1986	1991	1995	2000	2004	2009	2014
65	2018	2023	2028	2032	2037	2042	2046	2051	2056	2061
64	2065	2070	2075	2080	2084	2089	2094	2099	2104	2109
63	2113	2118	2123	2128	2133	2138	2143	2148	2153	2158
62	2163	2168	2173	2178	2183	2188	2193	2198	2203	2208
61	2213	2218	2223	2228	2234	2239	2244	2249	2254	2259
60	2265	2270	2275	2280	2286	2291	2296	2301	2307	2312
59	2317	2323	2328	2333	2339	2344	2350	2355	2360	2366
58	2371	2377	2382	2388	2393	2399	2404	2410	2415	2421
57	2427	2432	2438	2443	2449	2455	2460	2466	2472	2477
56	2483	2489	2495	2500	2506	2512	2518	2523	2529	2535
55	2541	2547	2553	2559	2564	2570	2576	2582	2588	2594
54	2600	2606	2612	2618	2624	2630	2636	2642	2649	2655
53	2661	2667	2673	2679	2685	2692	2698	2704	2710	2716
52	2723	2729	2735	2742	2748	2754	2761	2767	2773	2780
51	2786	2793	2799	2805	2812	2818	2825	2831	2838	2844
50	2851	2858	2864	2871	2877	2884	2891	2897	2904	2911
	9	8	7	6	5	4	3	2	1	0

	Transmission									
βt	9	8	7	6	5	4	3	2	1	0
49	2917	2924	2931	2938	2944	2951	2958	2965	2972	2979
48	2985	2992	2999	3006	3013	3020	3027	3034	3041	3048
47	3055	3062	3069	3076	3083	3090	3097	3105	3112	3119
46	3126	3133	3141	3148	3155	3162	3170	3177	3184	3192
45	3199	3206	3214	3221	3228	3236	3243	3251	3258	3266
44	3273	3281	3289	3296	3304	3311	3319	3327	3334	3342
43	3350	3357	3365	3373	3381	3388	3396	3404	3412	3420
42	3428	3436	3443	3451	3459	3467	3475	3483	3491	3499
41	3508	3516	3524	3532	3540	3548	3556	3565	3573	3581
40	3589	3597	3606	3614	3622	3631	3639	3648	3656	3664
39	3673	3681	3690	3698	3707	3715	3724	3733	3741	3750
38	3758	3767	3776	3784	3793	3802	3811	3819	3828	3837
37	3846	3855	3864	3873	3882	3890	3899	3908	3917	3926
36	3936	3945	3954	3963	3972	3981	3990	3999	4009	4018
35	4027	4036	4046	4055	4064	4074	4083	4093	4102	4111
34	4121	4130	4140	4150	4159	4169	4178	4188	4198	4207
33	4217	4227	4236	4246	4256	4266	4276	4285	4295	4305
32	4315	4325	4335	4345	4355	4365	4375	4385	4395	4406
31	4416	4426	4436	4446	4457	4467	4477	4487	4498	4508
30	4519	4529	4539	4550	4560	4571	4581	4592	4603	4613
29	4624	4634	4645	4656	4667	4677	4688	4699	4710	4721
28	4732	4742	4753	4764	4775	4786	4797	4808	4819	4831
27	4842	4853	4864	4875	4887	4898	4909	4920	4932	4943
26	4955	4966	4977	4989	5000	5012	5023	5035	5047	5058
25	5070	5082	5093	5105	5117	5129	5140	5152	5164	5176
24	5188	5200	5212	5224	5236	5248	5260	5272	5284	5297
23	5309	5321	5333	5346	5358	5370	5383	5395	5408	5420
22	5433	5445	5458	5470	5483	5495	5508	5521	5534	5546
21	5559	5572	5585	5598	5610	5623	5636	5649	5662	5675
20	5689	5702	5715	5728	5741	5754	5768	5781	5794	5808
19	5821	5834	5848	5861	5875	5888	5902	5916	5929	5943
18	5957	5970	5984	5998	6012	6026	6039	6053	6067	6081
17	6095	6109	6124	6138	6152	6166	6180	6194	6209	6223
16	6237	6252	6266	6281	6295	6310	6324	6339	6353	6368
15	6383	6397	6412	6427	6442	6457	6471	6486	6501	6516
14	6531	6546	6561	6577	6592	6607	6622	6637	6653	6668
13	6683	6699	6714	6730	6745	6761	6776	6792	6808	6823
12	6839	6855	6871	6887	6902	6918	6934	6950	6966	6982
11	6998	7015	7031	7047	7063	7079	7096	7112	7129	7145
10	7161	7178	7194	7211	7228	7244	7261	7278	7295	7311
09	7328	7345	7362	7379	7396	7413	7430	7447	7464	7482
08	7499	7516	7534	7551	7568	7586	7603	7621	7638	7656
07	7674	7691	7709	7727	7745	7762	7780	7798	7816	7834
06	7852	7870	7889	7907	7925	7943	7962	7980	7998	8017
05	8035	8054	8072	8091	8110	8128	8147	8166	8185	8204
04	8222	8241	8260	8279	8299	8318	8337	8356	8375	8395
03	8414	8433	8453	8472	8492	8511	8531	8551	8570	8590
02	8610	8630	8650	8670	8690	8710	8730	8750	8770	8790
01	8810	8831	8851	8872	8892	8913	8933	8954	8974	8995
00	9016	9036	9057	9078	9099	9120	9141	9162	9183	9204
	9	8	7	6	5	4	3	2	1	0

Rearranged by H. P. Gage

THE TOLEDO TRIAL CONCLUDED

Nine of the nation's leading glass container firms and 61 of their personnel were found guilty in the Toledo Federal District Court, held August 25, of charges of violating the Sherman and Clayton Anti-Trust Laws.

Judge Frank L. Kloeb named the following companies as guilty of charges brought against them in December, 1939, by Thurman Arnold, assistant U. S. attorney general: Owens-Illinois Glass Co., Toledo; Hartford-Empire Co., Hartford, Conn.; Empire Machine Co., Portland, Me.; Hazel-Atlas Glass Co., Wheeling, W. Va.; Thatcher Manufacturing Co., Elmira, N. Y.; Lynch Corp., Anderson; Ind.; Ball Bros. Co., Muncie, Ind.; Corning Glass Works, Corning, N. Y., and the Glass Container Association, Inc., New York City.

Filing of the decision, a 60,000 word document with James A. Green, clerk of Federal Court in Toledo, brought to an end the longest trial in the history of the Toledo court.

It was indicated that all nine of the defendant companies will appeal to the U. S. Supreme Court.

Judge Kloeb issued injunctions against all defendants, restraining them from engaging in what he called practices which have resulted in the present unlawful control and domination of the glass container industry.

This includes an injunction against any corporate defendant holding stock in any other concern in the industry and against all individual defendants from owning stock in more than one concern in the industry, and from being or becoming an officer or director in more than one concern in the industry.

In his 138 page opinion Judge Kloeb also filed a decree appointing James A. Shanley, New Haven, Conn., a member of the House of Representatives, as receiver for the Hartford-Empire Co. Mr. Shanley, an attorney, is 46 years old and is now serving his fourth term as representative from the Third Congressional District of Connecticut.

The demand of the government attorneys that Hartford-Empire be dissolved was turned down by Judge Kloeb who said that the court first will make an attempt to avoid such a step, if possible, and at the same time restore competition to the industry.

The attorney general's complaint had charged generally that the glass container companies violated anti-trust laws by "unlawfully conspiring, monopolizing, attempting to monopolize, and by unlawfully contracting, combining and conspiring to restrain interstate and foreign trade and commerce," and by acquiring and maintaining monopolies of patents covering the manufacture and licensing of glass-making machinery, manufacture and distribution of glass-making machinery, and manufacture, distribution and sale of glass products, and by "excluding others from the fair opportunity to engage freely and unrestrictedly in the interstate and foreign trade and commerce in said machinery and glass products."

Specifically the indictments charged violation with respect to patents on automatic machinery for production of pressed and blown glassware and glass containers; machinery for the production of pressed and blown glassware for glass containers, and the distribution of such machinery; the manufacture and distribution of pressed and blown glassware and particularly heat-resisting glassware, and the manufacture and distribution of all kinds of glass containers, milk bottles and fruit jars.

The judge ruled that the defendants will be enjoined from engaging in interstate commerce unless they comply with the orders of the court. They must license anyone, royalty free, on all present patents and pending applications for patents for the life of the patents; they must make available to anyone who desires them copies of drawings and patterns relating to suction devices, feeders, forming machines and lehrs.

The Glass Container Association was dealt with separately. Judge Kloeb's opinion was that this organization has engaged in unlawful practices through cooperation in furthering some aims of the conspiracy. Judge Kloeb said he has been shown that the association is a breeding place for many of the illegal practices established and provides a channel through which they are effectuated.

While holding that dissolution is not necessary, the Judge ruled that those activities of the Glass Container Association held to be unlawful must be halted.

Quoting from his opinion, "The court believes it best that it shall continue merely as a statistical and research body, and shall not go afield in an effort to dictate to the industry or be used for that purpose. Hence its personnel must be changed, including the membership of its board of directors and its officers.

"The new members are to be subject to the approval of the court and shall have no connection whatsoever with any of the defendants herein. The so-called statistical committee must be abolished and no committee of a like nature shall be established in the future."

Judge Kloeb ruled that there should be no doubt that an aggregation of patents collected into the hands of one or two large concerns, acting in combination with one another for the purpose of attaining control over an important industry in this country, is a violation of the anti-trust laws, especially when the means whereby these numerous patents have been acquired are unlawful.

Again quoting his decision: "In conclusion it may be said that Hartford-Empire, with the cooperation first of Corning and Empire and later, of Owens, Hazel-Atlas, Thatcher, Ball Brothers and Lynch, pursued a plan whereby, through threats of litigation backed by the financial power that it controlled, through litigation beyond the dreams of the average man, through the acquisition of the patents and businesses of competing devices and firms at a great outlay of money has corralled within its possession and control an aggregation of all the patents that pertain to the gob feed process in the manufacture of glass—one of the two automatic processes whereby glass containers may be made.

"This aggregation of patents for these machines has been strengthened through the acquisition of patents covering other devices necessary in the manufacture of glassware to the extent that all the patents covering these other devices, such as forming machines and lehrs, have been

(Continued on page 355)

THE DEVELOPMENT OF LOW MELTING GLASSES ON THE BASIS OF STRUCTURAL CONSIDERATIONS

By NORBERT J. KREIDL* and WOLDEMAR A. WEYL

PART I

EDITOR'S NOTE

In the past, the interest in the structure of glass has increased considerably since B. E. Warren and his school presented a picture of the glass constitution based on X-ray investigations. This picture has been extended to various glasses in many papers presented at the meetings of the American Ceramic Society and other national societies, and has been used as a basis for interpreting different properties such as electroconductivity, and thermal expansion. We have asked the authors to comment on the practical aspects of Warren's crystal-chemical conception of glass. Can this theory be used to predict properties so that it may be used as a tool in developing glasses with new properties, or does it serve only for explaining known phenomena? The authors have selected meltability as an example, to demonstrate how the modern theory of the glass structure can be practically applied.

We are accustomed to associate such desirable properties as good chemical resistivity, low thermal expansion and high mechanical strength with glasses of high melting temperatures. Indeed, glasses of the Pyrex brand type, the high alumina glasses of the top-of-the-stove ware type and, last but not least, vitreous silica justify this association. Most of the commercial glasses are the result of a compromise between the rather ideal qualities of fused silica and an improved meltability. For the purposes of this paper it will be convenient to define the melting temperature as the approximate temperature which, in a reasonable time, converts the raw batch into a glass of such fluidity that considerable homogeneity and freedom of gas bubbles is obtained. This definition is in agreement with the language of the practical glass man as well as with the terminology of various monographs and defines the "melting temperature" more or less as a "viscosity tempertaure" corresponding to a certain viscosity suitable for the melting process.

This temperature is not identical with the liquidus temperature of the composition used. Generally, these "melting temperatures," if plotted against composition, will not be comparable to the intricate liquidus curves, as obtained from phase equilibria studies.

As far as the main subject of this paper, the melting temperature, is concerned, the liquidus temperature is irrelevant. It will be of interest for the study of devitrification, since as long as the viscous glass is held at temperatures above the liquidus, devitrification is not possible. Although devitrification will not necessarily occur within reasonable time at temperatures slightly below the liquidus, the safest and most desirable condition for a workable glass will be a working temperature which is higher. Thus, Pyrex has the lowest liquidus curve of all known glasses, containing a similarly high amount of silica.

Glasses of relatively low melting temperature are desirable for many obvious reasons. With increasing melting temperature not only the cost of melting but also refractory attack and volatility increase rapidly. Inhomogeneity and formation of stones and cords are the consequence. Glasses of lower melting temperature are therefore, desirable as long as their meltability can be achieved without sacrificing other properties such as chemical resistivity. In certain fields of ceramics low melting glasses of reasonable resistivity are not only desirable but indispensable. This is the case whenever they are not used as independent materials but are applied to other materials which do not stand high temperature. The entire enamel industry is based on the existence of fairly resistive glasses of low melting temperature. The maturing range of glazes is limited in a similar way by the properties of the ceramic body.

The vitrifiable colors used in the decoration of glass ware are low melting glasses which must be fluid below the softening and deformation temperature of the glass ware. In the past decade, the requirements of the users of labeled bottles necessitated the development of such vitrifiable colors having a considerable chemical resistivity.

The low melting temperature of enamels, glazes, and vitrifiable colors is not only a requirement, but also offers a considerable advantage for the creation of a wider area of colors. The lower the maturing range, the greater is the selection of suitable pigments and opacifiers. Specifically, the choice of bright yellow and red colorants is decreasing rapidly with increasing temperature. From this point of view, low melting glazes may be desirable, even if the supporting material can stand higher temperatures such as, for instance, glazed roofing granules.

The efforts of the workers in this field have been aiming in two directions:

(a) The development of low melting eutectics for enamels, glazes, and vitrifiable colors with due consideration to the danger of impairing their resistivity.

(b) The improvement of chemical resistivity without impairing meltability. This goal has been approached very successfully in the development of acid-proof enamels.

One purpose of this paper is to correlate these properties and to investigate, from a structural view point, how the melting temperature of a glass can be lowered and which factors influence the chemical resistivity. Only if these two properties are thoroughly understood optimum conditions can be selected.

Another purpose of this paper is to demonstrate to the technologist, as well as to the industrial research worker, that because of Warren's interpretation, our conception of the structure of glass has reached a stage where it can be used for practical application.

Warren's fundamental approach was derived from strictly scientific view points. Nevertheless, he and his collaborators were able to correlate some of the basic properties, like thermal expansion, with the atomic arrangement. Later, other properties such as electroconductivity, color, and fluorescence had been explained in

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perfect agreement with Warren's picture. Our present knowledge of the structure of simple glasses, in combination with the experience of crystal chemistry, has not yet been used to plan new glass compositions with the aim of obtaining definite properties. It shall be demonstrated that even for this purpose the structural picture can be applied successfully.

It will be shown that certain approximations or simple rules can be used to advantage, even where the complete theory would be too complicated and where the actual structure of multicomponent glasses could not be established. Once a man who is engaged in development work has become familiar with these rules, he does not have to know the details of the atomic arrangement of the glasses in question.

In deriving such rules the calculation of the oxygen ratio of silicate glasses has been very useful. The following paragraphs describe the atomic structure of glass, the meaning of the term "oxygen ratio" and the influence of the oxygen ratio on the meltability of glasses.

STRUCTURE, OXYGEN RATIO AND MELTABILITY

1. Silica Glasses

The meaning of the term oxygen-silicon ratio is self-explanatory in the simple case of silica, SiO_2. The ratio of oxygen to silicon in the glass is 2 : 1, which also may be written 2. When comparing glasses of different oxygen-silicon ratios, it will become evident that this particular ratio of 2 is optimal for the formation of a continuous strong structure. First, however, we shall investigate how the oxygen-silicon ratio, commonly called the oxygen ratio, varies in soda-lime glasses.

Warren's X-ray work has furnished the proof for the fact that in soda-lime silicate glasses neither sodium nor calcium participates in the continuous structure of the silicon oxygen network. The sodium and calcium ions rather have to be satisfied with positions at some distance from the structural units in this network. These positions have been adequately termed "holes."

If we add Na_2O to silica only the oxygen of the Na_2O will participate in the silicon oxygen structure while the two Na^+ ions will assume such "hole" positions. This added oxygen will increase the oxygen ratio in the glass. This may easily be seen from Table I, which compares various additions of Na_2O to silica.

The addition of one mole Na_2O to 2 moles SiO_2 increases the oxygen ratio to 2.5 that of one Na_2O to one SiO_2 to 3, that of $2Na_2O$ to 1 SiO_2 to 4. The same holds true when calcium or both calcium and sodium are added. (Table II.)

Oxides, the cation of which is satisfied with the "hole" position and which furnish oxygen to increase the oxygen-silicon ratio of the structure are termed network modifiers, (N. W. M.). In most commercial soda-lime glasses the oxygen ratio is between 2 and 2.5. Two examples are given in Table III.

Indeed, a ratio of 4 will not permit glass formation. This can be seen easily from the following demonstration of the correlation of the oxygen ratio and the geometrical arrangement of the silicon and oxygen atoms in a silicate glass.

We know that crystalline silicates are built from tetrahedral units with silicon as the center and 4 oxygens

Addition of Na_2O →												
Composition	SiO_2			$Na_2O+2SiO_2$			Na_2O+SiO_2			$2Na_2O+SiO_2$		
	Na	Si	O	Na	Si	O	Na	Si	O	Na	Si	O
	-	1	2	2	2	5	2	1	3	4	1	4
Oxygen Ratio	2			2.5			3			4		

Table I. Calculation of the Oxygen Ratio of sodium silicate glasses.

Addition of CaO →												
Composition	SiO_2			$CaO+2SiO_2$			$CaO+SiO_2$			$2CaO+SiO_2$		
	Ca	Si	O	Ca	Si	O	Ca	Si	O	Ca	Si	O
	-	1	2	1	2	5	1	1	3	2	1	4
Oxygen Ratio	2			2.5			3			4		
	SiO_2			$Na_2O+CaO+4SiO_2$			$Na_2O+CaO+2SiO_2$			$Na_2O+CaO+SiO_2$		
Composition	Na,Ca	Si	O	Na,Ca	Si	O	Na,Ca	Si	O	Na,Ca	Si	O
	-	1	2	3	4	10	3	2	8	3	1	4
Oxygen Ratio	2			2.5			3			4		
Addition of Na_2O+CaO →												

Table II. Calculation of the Oxygen Ratio of simple lime and soda lime glasses.

		Sand	Soda	Lime
		100	29	3
Composition	$Na_2O+CaO+6SiO_2$			$17Na_2O+12CaO+100SiO_2$
	NWM: Na,Ca	Si	O	NWM: Na,Ca	Si	O
	3	6	14	46	100	229
Oxygen Ratio	23			229		

1) Network Modifying Ions

Table III. Calculation of the oxygen ratio of Commercial Soda Lime glasses.

at the corners. Warren proved that this group is also the building unit of silicate glasses; only the somewhat irregular arrangement of the identical units differentiates the structure of the glass from that of the crystalline silicates.

As 4 oxygens, each having the valency of 2, surround one silicon of the valency 4, obviously 4 valencies or one valency for each oxygen remain unsaturated. (Fig. 1).

Number of Ions	Total Valency
4 Oxygen X − 2	− 8
1 Silicon X + 4	+ 4
Unsaturated Valency	−4
½ to Per Oxygen	−1

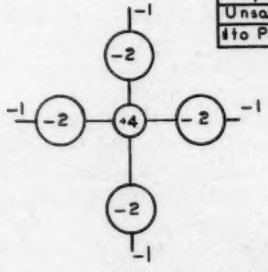


Fig. 1. Unsaturated valencies at the corner of a $Si-O_4$ tetrahedra.

Hence, the tendency of each of the 4 oxygens to become attached to another silicon, that is to share two silicon oxygen tetrahedra; and hence, the formation of a continuous network, if the ratio of silica to oxygen is just right. If each of the four oxygens surrounding one silicon participates in two silicon tetrahedra, the ratio oxygen to silicon obviously will be: $4 \times \frac{1}{2} = 2$. Consequently, the oxygen ratio 2 is just right for the strongest continuous tetrahedral oxygen network and SiO_2, as mentioned before, is the ideal, and at the same time the strongest glass in the silicate series. If more than two oxygens per silicon are present, there are not enough silicon ions available for two of them to share each oxygen. Figure 2 shows how many oxygens still can be shared for the oxygen ratios 2.5, 3, 3.5, and 4.

In all five cases listed in this table one silicon is always surrounded tetrahedrally by four oxygens. But in the first column, at an oxygen ratio of 2, all four oxygen ions share two neighboring tetrahedra, which is indicated by a little bar at the circles in the structure sketches, symbolizing oxygen (O—). In the second column, at an oxygen ratio of 2.5, only three oxygens are shared, in the third two, in the fourth one, in the last none.

If no oxygen is shared by two tetrahedra, no continuous network and, consequently, no glass can be formed; nor is there much chance for glass formation, if only one or two oxygens are shared. The metasilicate glasses (Na_2O+SiO_2), with an oxygen ratio of 3 corresponding to only two oxygens shared, are weak and unstable and represent the borderline of practically obtainable glasses. Between the first and second column, at oxygen ratios from 2 to 2.5, where from 4 to 3 oxygens are shared by neighboring tetrahedra, the commercial glasses are located. They exhibit decreasing strength and increasing meltability as one proceeds towards 3 oxygens shared.

At the bottom of each column crystalline silicates of the same oxygen ratio are listed. Instead of a gradually loosened three dimensional network, the symmetry of the crystalline arrangement requires two dimensional sheets and one dimensional chains as the oxygen ratio increases. Thus two dimensional sheets of $Si\text{-}O_4$ tetrahedra, such as mica, appear when at an oxygen ratio of 2.5 only 3 oxygens are shared. One dimensional chains occur at an oxygen ratio of 3, where only two oxygens are shared by neighboring tetrahedra, such as in the case of diopside ($MgCaSi_2O_6$). These chains may be represented schematically in Fig. 3.

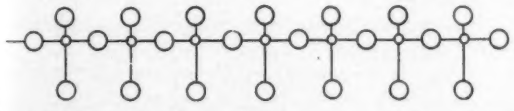


Fig. 3. Chain of $Si\text{-}O_4$ tetrahedra in crystalline silicates of Oxygen Ratio 3.

In glasses this symmetry does not exist. With increasing oxygen ratio the three dimensional network is still maintained, no chains or sheets have to form, but the three dimensional network is disrupted in an irregular way.

2. Other Glass Forming Oxides

In silicate glasses it is relatively easy to determine the oxygen ratio and to correlate it with the meltability of the glass. The results of a discussion of this correlation may be summarized:

(a) The lowest oxygen silicon ratio is 2. It occurs in SiO_2 glass and causes a continuous, strong, three-dimensional network of high melting temperature.

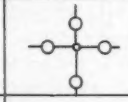
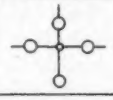
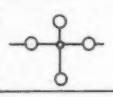
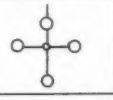
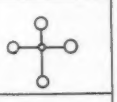
(b) The addition of "modifiers" such as Na_2O or CaO increases the oxygen ratio and decreases the melting temperature. At values above 3 the network is disrupted so that devitrification becomes more frequent, and at the ratio 4 no glass formation is possible. The cations of the modifiers do not participate in the network and are satisfied with hole positions.

SiO_2 is not the only glass forming oxide and the silicon ion is not the only ion which permits the arrangement of a continuous tetrahedral network. The exact geometrical conditions for tetrahedral arrangement call for central ions which are between 0.225 and 0.414 times the size of the oxygen ion. Since the latter is 1.32 A°, the glass forming ions must have a size between 0.3 and 0.55 A°. The size of the silicon ion is 0.41 A° and satisfies this condition very well. Other conditions may be outlined briefly as follows: The valency should be high enough to bind the four surrounding oxygens tightly, but should not be as high as to prevent four oxygens from hooking up with the next neighbor ions. From this consideration the optimal valencies are four to five. Silicon fulfills these further conditions with its valency of four. Ions which are too small or have a higher charge than these permissible limits attract their surrounding oxygens so strongly that the tendency to form continuous networks disappears and volatile compounds are formed instead. Examples are CO_2, where the carbon ion has a radius of only 0.15 A° and SO_3, where sulfur shows the higher valency of 6.

Only one of the smaller ions, boron, is able to form glasses of a different type, consisting of $B\text{-}O_3$ units where the oxygens are arranged in triangles and interlinked in a way that a relatively weak threedimensional structure results.

In view of these limiting factors and disregarding some

Fig. 2. Structure of Silicate glasses and crystalline silicates.

Composition	SiO_2	$Na_2O+2SiO_2$	Na_2O+SiO_2	$3Na_2O+2SiO_2$	$2Na_2O+SiO_2$
	Na Si O – 1 2	Na Si O 2 2 5	Na Si O 2 1 3	Na Si O 6 2 7	Na Si O 4 1 4
Oxygen Ratio	2:1=2	5:2=2.5	3:1=3	7:2=3.5	4:1=4
Structure in Plane					
Oxygen Shared With Next Tetrahedron	4	3	2	1	0
Shared Oxygens Per Silicon	$4\times\frac{1}{2}=2$	$3\times\frac{1}{2}=1.5$	$2\times\frac{1}{2}=1$	$1\times\frac{1}{2}=.5$	$0\times\frac{1}{2}=0$
Unshared Oxygens Per Silicon	$0\times1=0$	$1\times1=1$	$2\times1=2$	$3\times1=3$	$4\times1=4$
Sum=Oxygen Ratio	2	2.5	3	3.5	4
Behavior of Glass	Pyrex Strong High melting	Normal Glasses Soft Less Resistive	Tendency to devitrify	→ Unstable	No glass formation possible
Structure of Crystalline Silicates Equal Oxygen Ratio	Three dimensional network like glass but symmetrical	Two dimensional sheets of $Si\text{-}O_4$ tetrahedra	Rings or chains of $Si\text{-}O_4$ tetrahedra	Two tetrahedra linked at one oxygen	Isolated tetrahedra
Examples	SiO_2 Quartz, Cristobalite, Tridymite	Mica	Diopside (chain) $CaMg(SiO_3)_2$ Beryl (ring) $Be_3Al_2(SiO_3)_6$ Asbestos (chains)	Mellilite $Ca_2MgSi_2O_7$	Fosterite Mg_2SiO_4

→ Addition of Na_2O

Oxygen Ratio Calculated From Formula (1)	2	2.5	3
(2) Composition Silicate Series	SiO_2	$Na_2O + 2SiO_2$	$Na_2O + SiO_2$
	Na: –; Si: 1; O: 2	Na: 2; Si: 2; O: 5	Na: 2; Si: 1; O: 3
(3) Phosphate Series	does not exist	P_2O_5	$Na_2O + P_2O_5$
		Na: –; P: 2; O: 5	Na: 2; P: 2; O: 6
Shared Oxygens (4)	4	3	2
Shared Oxygens per P or Si (5)	$4 \times \frac{1}{2} = 2$	$3 \times \frac{1}{2} = 1.5$	$2 \times \frac{1}{2} = 1$
Unshared Oxygen per P or Si (6)	$0 \times 1 = 0$	$1 \times 1 = 1$	$2 \times 1 = 2$
(7) from (5)+(6) Sum = Oxygen Ratio calculated from structure model	2	2.5	3
from (2) Ratio $\frac{Na^+}{Si}$ in Silicate glasses	0	1	2
from (3) Ratio $\frac{Na}{P}$ in Phosphate glasses	does not exist	0	1

Fig. 4. (left). Na+ content of Phosphate and silicate glasses of equal oxygen ratio.

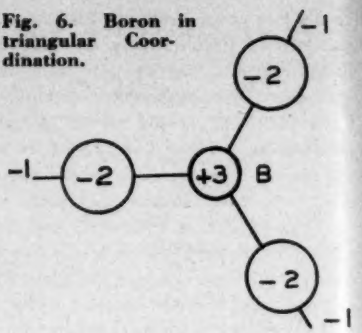


Fig. 6. Boron in triangular Coordination.

rarer elements, glass formation is limited to B_2O_3, P_2O_5, and SiO_2. Phosphorus has an ionic radius of 0.34, and also satisfies the conditions for a tetrahedral network.

Thus silicon, phosphorus and boron are network formers (N.W.F.). If we now contemplate the oxygen ratio of P_2O_5 and its combinations with for instance, Na_2O we can proceed just as in the case of silicates and determine the oxygen ratio by comparing the total oxygen content with the phosphorus content without considering the sodium in its hole positions. This procedure is justified, because Warren's X-ray analysis of phosphate glasses revealed the presence of $P\text{-}O_4$ tetrahedra with the modifying ions in the "hole" positions. But the results of our simple and analogous calculation will immediately appear to be strikingly different from those obtained with silica and silicates. Phosphorus has a valency of five. Consequently the pure oxide having the formula P_2O_5 already contains an excess of oxygen over that required for the continuous network. Phosphate glasses, therefore, do not need the addition of alkali in order to possess an oxygen ratio similar to that of soda-lime glasses. On the contrary, the oxygen ratio of the pure phosphorus pentoxide, P_2O_5 is 2.5, that is rather high and corresponds, if the silicon is replaced by phosphorus in Fig. 3, to an arrangement of tetrahedra connected only by 3 of their 4 oxygen corners. In this way the pure P_2O_5 glass corresponds to the sodium disilicate ($Na_2O.2SiO_2 = 2Na$, 2Si, 5 O) glass rather than to silica.

Figure 4 reveals the oxygen ratio and tetrahedral interlinkage of phosphate and silicate glasses, on the basis of a comparison of equal oxygen ratio. This comparison shows that the phosphate glasses of equal oxygen ratio contain less alkali ions than the silicate glasses. We have seen that, as a rule, the high oxygen ratio is indicative of a low melting temperature. We can express the result of the comparison represented in Figure 3 by saying: A phosphate glass of approximately the same meltability as a silicate glass contains less alkali.

Even the lowest oxygen ratio of any of these phosphate glasses, namely that of P_2O_5, is still higher than that of the lowest melting commercial silicate glasses. The experimental evidence is, indeed, that P_2O_5 like sodium disilicate forms very low melting, but unstable glasses.

The oxygen ratio is only one of the causes of low meltability. Only when discussing the other causes and correlating the corresponding structures to the chemical resistivity, we shall be able to see that resistive phosphate glasses of low melting temperature can be synthesized. But always the fundamental truth expressed in Figure 6 will remain apparent, namely, that to be equally fluxed the P_2O_5 glasses require less Na_2O than do the SiO_2 glasses. This is also one of the fundamental backgrounds of the development of relatively soft phosphate glasses of high electrical resistivity. In Fig. 5 the attempt is made to illustrate this connection graphically.

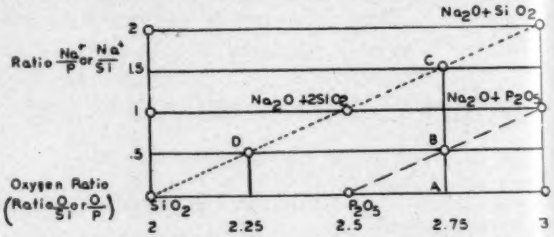


Fig. 5. Na+ content of phosphate and silicate glasses (graphically).

The amount of sodium ions per glass forming cation (S_i, P) is plotted against the oxygen ratio. All possible sodium silicate glasses lie on the dotted line. The line ABC connects glasses of the constant oxygen ratio 2.75 and we find that the silicate glass C contains three times as many Na^+ ions (1.5Na^+per Si) than the corresponding phosphate glass B (0.5 Na^+ per P). If we compare the same phosphate glass B with the silicate glass of equal relative sodium content, the phosphate glass B has a higher oxygen ratio (2.75) than the corresponding silicate glass D (2.25), which makes the phosphate glass of equal Na^+ content more meltable.

We have discussed the main factor which causes the decrease of melting temperature, namely, the increasing oxygen ratio. Other structural changes also contribute to the meltability.

In order to discuss all possible structural changes, having this effect, we have to understand the nature of the three principal constituents of a glass namely:

1. Oxygen, providing the network proper which is closely packed and, therefore, determines the bulk of the volume of the glass.

(*Continued on page* 357)

DETERIORATION OF OLD WHISKEY BOTTLES

By ALEXANDER SILVERMAN* and LEONARD G. GHERING**

History

A Pittsburgh friend of one of the authors has kept in storage since about 1918 several cases of rye whiskey in quart bottles. Fifteen years ago eighteen bottles showed a crackled appearance, and a part of their contents had been lost by diffusion. Last year it was observed that all the crackled bottles were empty. The bottles were riddled with cracks and had check marks (see illustration) and were of a very sorry appearance. The question of what was wrong with the crackled bottles or the contents therefore arose.

So far as is known, the bonded liquor was bottled about 1918 and has been stored in a private home ever since. The labels and scale are still on the bottles, perfectly clean and legible. There is no evidence that the bottles have ever been excessively hot and wet.

Description

The bottles are round quart size, amber, made by the suction machine process, and have a cork finish. The glass is not cordy and is well annealed.

On the defective bottles, the cracks start on the outside face of the bottle, at many different places, presumably bump checks. They are of the slow traveling type, and meander somewhat aimlessly about, indicating that they are due to local stresses and not to a general stress system operating on the bottle as a whole. These cracks are filled and discolored with decomposition products, and resemble the cracks sometimes found in more recent bottles which are low in lime, high in soda, and have been subjected to a prolonged heat treatment in saturated steam or hot water, resulting in breakage by an "etching-decomposition-wedging" process.

Such cracks in a less extreme form have been illustrated by J. Bailey,[1] Jebson-Marwedel[2] and others.

Analysis of Glass

It is interesting to examine the glass composition of both the crackled and the unbroken types of bottles from the same case.

The analyses are given in Table I, silica having been determined by difference.

TABLE I.

	Crackled Bottles	*Intact Bottles*
Na_2O	22.06	18.00
CaO	3.51	8.40
MgO	.57	none
R_2O_3	.70	.24
BaO	none	
SO_3	.16	.23
SiO_2	73.00	73.13

It would seem that the crackled bottles are 5 or 6 per cent high in soda, and at least 5 per cent low in R.O.

They cannot be expected to have any durability, and a quarter of a century at ordinary room temperatures and humidities seems to have been the limit of their endurance.

The composition of the "Intact" bottle glass is within the range of early machine made bottle glass as illustrated by Table II.

TABLE II.

	Above amber whiskey bottle (1918)	*Representative machine made container glass* (1933)*	*Gob-fed machine flint* (1915)**	*German Owens machine amber***
Na_2O	18.00	17.0	17.40	19.02
CaO	8.40	5.0	4.80	7.77
MgO	none	3.5	3.60	1.53
R_2O_3	.24	.5	.50	.25
So_3	.23	none	none	MnO .45
SiO_2	73.13	74.0	72.43	70.54

*Sharp, D. E., Ind. Eng. Chem. 25, 755 (1933).
**Scholes, S. R., Modern Glass Practice, 1941, p. 42.

pH of the Contents

A test of the rye whiskey from a bottle that was not broken shows a pH of 4.5. Whiskey is normally bottled in a very acid state with a pH of about 4.5. Since the contents of the cracked bottles were lost, it was impossible to get the pH of the whiskey in the glass bottles in question. However, since the cracks started on the outside surface, it is not suspected that the contents had anything to do with the breakage.

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**Preston Laboratories, Butler, Pennsylvania.

[1]James Bailey, "On Chemical Durability," Glass Ind. 15 (8) 171-73 (1934).

[2]Hans Jebsen-Marwedel, Glastechnische Fabrikationsfehler, p. 244, Julius Springer 1936 (Berlin).

FOAM GLASS

Part III of a Series of Articles on the Development and Uses of Foam Glass

By E. L. KREIDL

PROCESSES FOR THE PRODUCTION OF FOAM GLASS

In the following the various processes for the manufacture of foam glass are discussed in connection with the existing patent literature. In assembling these data it was endeavored to cover completely the domestic patents, while the foreign patent literature was only considered where it was conveniently accessible or where corresponding domestic patents either do not exist or are not yet granted. In the appended Bibliography the patents are arranged according to countries and date and cross-referenced where corresponding patents have been listed.

Pioneer work has been done by Slayter in this country and by Long in France. The early inventions of these two inventors cover practically all important basical methods for the production of foam glasses. Most of the important engineering developments which finally lead to the processes now in use are to be found in the patents of the Pittsburgh Plate Glass Co., especially the contributions of Haux and Lylle and co-workers. The extremely short period of time in which the various methods were developed make the disclosures of the patents somewhat overlapping and it appears that often broad disclosures lead to rather restricted patent claims only. Since it is not the purpose of this paper to investigate which methods are covered by which patents it was principally endeavored to discuss each patent in connection with its teachings which may be of special interest to the ceramist. Nevertheless, where several patents deal with more or less the same subject matter, such subject matter is discussed primarily in connection with the patent in which it is claimed. In discussing the patent literature it was also found to be convenient to group them according to the same principles as used in the preceding section. In a separate group E some miscellaneous patents which do not specifically fall under any of the groups A to D will be discussed.

A. From Seedy Glasses

The expansion of seedy or bubbly glass under the influence of a vacuum is disclosed in U. S. patent 2,119,259 by Slayter.[17] Obviously in connection with research on the production of seamless hollow bricks he discovered that seedy unfined glass when subjected to a vacuum will expand into a lightweight foamy glass. In carrying out this method a charge of seedy molten glass is introduced into a mold which then is rapidly exhausted. The glass under the influence of the vacuum will expand and fill out the mold. The chilling effect of the surfaces of the mold will cause the outer walls of the shaped article to be denser and accordingly stronger than the interior.

A similar process was developed by the French firm St. Gobain and lead to the French patent 781,050.[45] To obtain a sufficiently seedy glass a glass melt or glass cullet is heated to 1400°C. by which expedient the dissolved gases are released. The molten vesicular glass then is transferred into molds which have been preheated to 400°C. and subjected to a reduced pressure. The individual gas bubbles will expand and as the temperature drops the glass will solidify sufficiently to prevent escape of the gases. The resultant cellular glass then is reheated to 600°C. and cooled slowly in a lehr.

In further development of the process of this French patent Lambert, U. S. patent 2,143,951,[19] devised a method by which the glass which had been heated to 1400°C. is poured into a shallow receptacle with a flat bottom over which a mold with an open bottom is pressed. Preferably this mold is divided by partitions into a multi-compartment mold, vacuum being supplied to the several compartments by means of a manifold. In this way a number of separate units may be molded on the shallow receptacle which will be only connected by thin glass strips which can be easily broken apart. The density distribution of the formed foam glass may be regulated by the speed with which the vacuum is supplied to the molds. On rapid evacuation the density will be fairly uniform, while on slow evacuation the density will decrease from the bottom and the edges of the molds up to the neighborhood of the cover. Blocks having layers of different densities may be prepared by introducing separately into the mold layers of varying gas bubble content. Although not described in this patent it appears to be quite obvious that in this manner it would be also possible to make blocks or other shapes having one or more surfaces of solid glass by first introducing a layer of solid fined glass and then layers of seedy glass.

The addition of refractory materials, such as sand, to obtain a seedy glass which then may be expanded as described in the above mentioned Slayter patent[17] is disclosed in another patent by Slayter, U. S. patent 1,967,375.[15] Lytle in U. S. patent 2,215,223[23] mentions the use of vermiculite for the same purpose. The addition of sand to molten blast furnace slag in the production of porous slag according to French patent 647,573 of Jan. 27, 1928, obviously serves the same purpose. Several other patents for the production of foam glass mention the addition of refractory materials as fillers rather than as gassing agents.[40 24]

B. Long in U. S. patent 2,123,536[18] also mentions talc powder and kieselguhr as gassing agents, however, in connection with the use of crushed glass.

B. From Glasses Containing Special Ingredients, Causing Gas Evolution in the Softening Range

The processes falling into this group have been developed by B. Long. According to his earlier process, U. S. patent 1,945,052[14], a glass is prepared from a batch rich in gas evolving substances such as carbonates, hydrated boric oxide, and hydrated aluminum oxide and also containing oxides like titanium dioxide or zinc oxide. After melting, the glass is either cooled or reheated to a temperature near the softening range to obtain swelling.

For example, a glass of the following composition may be used: Sand 100, borax 94, ZnO 17, Aluminum Hydrate 5, Carbon 8. For the preparation of foam glasses according to this process the use of borosilicates is essential, obviously because of the greatly increased water retention by such glasses. This process was greatly improved by a later invention of Long, U. S. patent 2,156,457[20] which made it possible to apply this method to ordinary soda-lime glasses. According to this process oxides having the tendency of splitting off oxygen at high temperatures, such as titanium dioxide, manganese dioxide and chromic oxide, are added to the raw batch together with a reducing metal powder, such as aluminum powder. The foam glass then may be prepared exactly as according to his older method. The application of vacuum is said to be advantageous for the foaming of the glass. A suitable batch for this process, for example, is: Sand 852, Sodium Carbonate 375, Limestone 195, Titanium Dioxide 24, Aluminum Powder 5.

A method for continuously preparing a sheet of foam glass according to any of the processes where foaming occurs on heating under reduced pressure is described in U. S. patent 2,118,707 by Ingouf.[16] A glass, for example, as prepared according to the above described process by Long[14] is withdrawn from the furnace in the form of a sheet and scored with a scoring knife. Then it is rapidly cooled between jets of air and introduced into a chamber in which it is subjected to a temperature above its softening point and to reduced pressure. The glass is guided through this chamber on a conveyor the sidewalls of which limit the expansion of the foam glass in horizontal direction. After expansion the glass is sized between rolls and cooled in a lehr.

C. By Introducing Gases into Molten Glass

The addition of a solid gas evolving agent, such as charcoal, to molten blast furnace slags in the production of lightweight slag has been disclosed in the previously mentioned French patent 647,573.

The possibility of introducing calcium carbonate into molten glass to convert it into a foam glass is mentioned in U. S. patent 2,261,022 by Fox and Lytle[30] and a similar process for slags also mentioning the use of magnesium carbonate may be found in U. S. patent 1,947,488 of Feb. 20, 1934, by R. C. Newhouse which deals with a process for the production of slabs, blocks and aggregates from molten slag and ground limestone and magnesite.

U. S. patent 1,912,017 by Slayter[13] deals with the preparation of foam glass or slags having a vacuum in the cells of the foam. This is obtained by mixing into the molten glass substances which evaporate at temperatures lower than the melt and which solidify at a lower temperature than the glass.

As far as the introduction of gases and vapors into the molten mass is concerned again the processes for the production of slags have preceded those devised for the manufacture of foam glass. Just by way of example, the following slag patents may be mentioned. French patent 682,556 of Oct. 1, 1929, describes a process for the preparation of lightweight slag in which the molten slag is poured on a rotating grooved wheel on which water is sprayed. In a similar way according to British patent 350,035 of Jan. 28, 1930, the molten slag is poured over a slowly rotating wheel in the periphery of which a plurality of bowl shaped cavities are arranged in which water or other liquids, vapors or gases are brought into contact with the molten slag to effect swelling. The Russian patent 26,956 of Aug. 25, 1931, describes a process according to which porous products from blast furnace slag are prepared by blowing air through a porous partition into the molten slag.

According to the process by Lytle, U. S. patent 2,215,223,[23] even distribution of the gas bubbles may be obtained regardless of the fact whether they are formed by the addition of refractory materials, carbonates, air or steam. According to this process, molten glass is fed into a vertical chamber which is kept at a temperature well above the softening range of the glass. This chamber may be a continuous vertical melting furnace or just a tank receiving the molten glass from the melting furnace proper. The bottom of this chamber is connected to a horizontal conduit by means of a slightly upwards inclined duct. Steam is blown from above into said conduit, or refractory materials, such as vermiculite, or carbonates are fed into it from above by means of a worm drive to mix the glass with the desired amount of gas bubbles. By means of the hydrostatic pressure in the vertical chamber the bubbly glass is pressed from this conduit through an inwardly flared tip into an outwardly flared nozzle—which together form something like a venturi throat—and fed to a vertically spaced conveyor unit. The conveyor unit is arranged in an evacuated chamber in which expansion of the bubbly glass is effected. Instead of feeding such a glass into the conveyor unit, it may be cut into gobs and dropped into molds in which it may be subjected to reduced pressure.

In a patent by Lytle and Miller, U. S. patent 2,233,631,[25] a process is described according to which a fluid, such as air or superheated steam, is blown into the melt, preferably through a porous wall. Thus, the forehearth of a melting furnace may be built from porous bricks which may be surrounded by a jacket tightly sealed thereto. The fluid will be pressed into the melt through the porous brick wall. Alternatively the molten glass may be poured into porous molds having a non-porous cover plate. The molds then may be placed into a jacket and the fluid may be pressed into the glass from the jacket exactly as in the first case. Another feature described in this patent is the application of a vacuum over the molten glass simultaneously with the introduction of the fluid.

Black, U. S. patent 2,272,930,[33] describes a method in which a crust of glass may be formed on the surface of a foam glass which has been made by pressing gas through a porous bottom by providing a metallic insert near this porous bottom which may be inserted into the bottom part of the mold before the glass has frothed up to the top.

Stirring air into molten glass as a means to obtain a bubbly glass which then can be expanded under vacuum is mentioned in the previously discussed patent by Slayter.[13] Actual application of the egg beating method is described in the German patent 673,796 by Fabian & Co.[58] According to this process glass is heated to a temperature at which it has the viscosity of egg white and is beaten so as to mix it with the hot furnace gases. In-

stead of the furnace gases other gases which have been preheated to the temperature of the glass may be blown into it.

Goldis in a paper on multicellular glass[3] describes a process according to which liquid glass is pumped into an autoclave together with air which is heated to 1400°C. so as to cause rapid ebullition and elongation of the gas cells. The resulting glass which has the trade mark "Lignoverre" is reported to have practically woodlike properties. Criticism with respect to these claims[4] has been mentioned in an earlier part of this paper.

D. By Introducing Gases into Sintering Crushed Glass

Inflation of sintering crushed glasses is described in the following patents. The first group of patents will deal with processes in which fluids are introduced as such.

According to the process of U. S. patent 2,255,236[28] by Willis, ground glass is fed through a tube under slight mechanical pressure by means of a hand operated plunger. The glass will be sintered at 1100°F. while an air pressure of about 50 to 100 lbs. per square inch is applied. The sintered material then is forced into another kiln and heated to 1500 to 1800°F. so that due to the decreased viscosity of the glass it will expand into a lightweight cellular product. The expansion may be either limited by closed molds or may be free. It is explained that the cell size may be decreased by one or all of the following means: closer packing of grains; increased mechanical or fluid pressure; increased sintering temperature; decreased expansion temperature; slow cooling to annealing temperature. Patent 2,255,237[28] by the same inventor describes a reciprocating feed mechanism instead of a screw feed and a suitable lining for the sintering tube. Patent 2,255,238[28] also by the same inventor discloses the use of moistened crushed glass, obviously to increase the gas pressure.

U. S. patent 2,237,037,[27] by Lytle, deals with a process in which crushed glass and water are mixed in a closed container. On heating, the softening glass will entrap the formed steam, which, since the heating has been carried out in a closed container, will be under pressure. The vesicular glass then is removed from the closed container and will greatly expand when getting into the outside atmosphere. The expansion will be further increased due to the fact that fairly large amounts of water which under pressure were adsorbed in the glass will form finely distributed gas bubbles on the subsequent pressure release. It is mentioned that other gases under pressure will act in the same way.

Lytle, U. S. patent 2,264,246,[31] describes a process for the manufacture of foam glass from crushed glass with gases under pressure which otherwise corresponds in all details to the process of U. S. patent 2,234,037 by the same inventor,[27] which has been discussed above.

Some of the following processes, namely those which deal with the use of carbonates or carbon in ordinary crushed glasses are closely related to those which at present are in actual use. Generally such glasses will contain both air, which has been in the interstices between the crushed glass, and gases which are formed by the gassing agent. The density of such glasses may be controlled by the quantity of the gassing agent, by the fineness of the crushed glass, by the sintering temperature, by the duration of the sintering treatment and by the cooling rate.

The broadest patent in this group is the U. S. patent 2,123,536 by B. Long.[18] This patent broadly contemplates the production of foam glass by heating solid comminuted vitreous substances in admixture with pulverized substances which are capable of producing gases at the temperature at which the glass softens sufficiently to envelop the evolved gases. With the striking exception of carbonates, this patent gives examples of most of the important types of gassing agents. The importance of this patent makes it sufficiently interesting to give a detailed description of the examples. Coal may be used as a gassing agent and an addition of .5 parts vegetable coal with 100 parts glass can be utilized to prepare a foam glass the apparent density of which is .40 when heating the mixture to 800 to 900°C. Coal, but also other carbon containing substances such as carbides, or other reducing substances such as silicon or ferrosilicon, also may be used in combination with substances with which they can react to form gases at the softening temperature. Thus 30 parts of carborundum may be mixed with 70 parts of a glass containing .3 per cent of SO_3. On heating the glass to 800 to 900°C, SO_3 will be reduced to SO_2 and given off as a gas and the carborundum will be oxidized to silica and CO. The glass will have an apparent density of about .35. Alternatively sodium sulphate may be mixed with the reducing agent and the crushed glass. Thus, 90 parts glass, 3 parts finely pulverized silica, 6 parts sodium sulphate and 1 part coal when heated to about 850°C. will give a glass of an apparent density of about .45. The finely pulverized silica is added to react with sodium sulphide which is formed by the reaction of the sodium sulphate with coal. The addition of hydrated substances is illustrated by the addition of hydrated magnesium silicate (talc) to the crushed glass. On heating the evaporized hydration water will swell the glass. Finally, porous substances like kieselguhr or infusorial earth which retain air or water strongly may be used as gassing agents. Instead of crushed glass, a glass which was only fritted at 700 to 800°C. may be used. To prevent sticking the use of graphite molds is recommended and pre-heating of the molds to the softening temperature is said to be advantageous. In this respect see also British patent 447,821.[37]

Haux in U. S. patent 2,191,658[21] discloses a method for preparing cellular insulating bodies from crushed blast furnace slags or glass. The crushed glass is mixed with calcium carbonate and the mixture heated to a temperature at which the glass will coalesce. The temperature then is sufficiently raised to decompose the carbonate. Then the temperature is further raised to about 1600 to 1750°F. to further decrease the viscosity of the glass so that the gases can readily expand the glass. To obtain satisfactory results the glass should be crushed to completely pass through a 28 mesh sieve, while being too coarse to pass through a 200 mesh sieve. The addition of calcium carbonate should be about 1 to 2 per cent of the glass. It is mentioned that charcoal and other gassing agents may be used in the same way as calcium carbonate.

Apparatus for withdrawing foam glass from a chamber in which it is formed either horizontally or vertically is

described in detail in U. S. patent 2,261,022 by Fox and Lytle,[30] The process used for producing the foam glass is in its main features the same as the one of the preceding patent.[21] The top layer of a thus formed foam glass is continuously withdrawn either as a continuous sheet or is continuously cut into bricks or the like. The described process is equally suitable for foam glasses prepared in other ways.The foaming may be increased by blowing air into the line of draw out of the gassing chamber.

The incorporation of porous materials, such as vermiculite into foam glasses of the above described type is the main feature of U. S. patent 2,233,608 by Haux and Lytle.[24] Incorporation of such porous materials is claimed to improve the overall properties of the material and reduce substantially the annealing time required.

The use of potassium carbonate and of sulfates is mentioned in a paper by Kitaigorodski and Butt.[5]

An apparatus for making foam glass blocks may be found in U. S. patent 2,257,681 by Haux.[29] The main feature of this patent is the use of molds which have removable sidewalls and cover plates. At one end of the continuous system the molds are charged with crushed glass and calcium carbonate. The molds are closed and conveyed through a tunnel kiln where they are heated sufficiently to cause sintering of the glass and decomposition of the carbonate. The molds are then passed through a cooling zone. When the glass is sufficiently solidified the molds are stripped of their sidewalls and cover plates and conveyed through a lehr. The removal of the sidewalls and cover plates prior to annealing is said to cut down on annealing time and prevent cracking due to the difference in expansion of the mold and brick. The cover lid may be arranged as to be freely removable in vertical direction so that it will be moved up by the expanding foam glass. Thus a flat surface of the block is assured and crust formation may be prevented.

The use of inert fillers such as sand and clay in foam glasses from crushed glass and substances like calcium carbonate is mentioned in British patent 490,168.[40]

A foam glass similar to that disclosed by Slayter[13] which was discussed under C. is described in U. S. patent 2,012,617.[15a] Zinc, cadmium or similar metal powders are mixed with glass and the mixture is heated to the melting temperature. Then the pressure over the glass melt is lowered to permit the metal powders to evaporate. The thus formed foam glass then is cooled under vacuum. The resultant foam glass then will contain the condensed metals in its cells, which will be more or less evacuated. Foam glasses having condensed metals within their cells are broadly claimed in this patent. German patent 668,592[56] is practically identical with the preceding process.

According to British patent 486,623[39] the efficiency of this process may be greatly increased by adding substances which react at these temperatures under the evolution of heat without giving off any gases. "Thermite," that is, a mixture of aluminum powder and iron oxide, will be suitable for this purpose.

According to the British patent 529,725,[43] powdered glass is mixed with a gas generating substance in a tightly closed steel container. When the glass is foamy, internal superatmospheric pressure is produced by introducing compressed air. The formed foam glass is pressed out through a narrow opening and cooled sufficiently fast to prevent collapse of the cellular structure.

E. Miscellaneous Processes

Where foam glass is not just used as an enclosed insulating layer but as a self-supporting structural unit similar to the use of hollow glass bricks both the mechanical strength of the blocks as well as its surface hardness and appearance may become important. Also in some cases it will be convenient to manufacture the foam glass in large sheets or blocks and then to cut it to size for any particular application. This will be particularly convenient since foam glass can be easily sawed or otherwise shaped with ordinary carpenter tools and the necessity of having to have a variety of molds is eliminated. However, the cut surfaces will be rough, and objectionable where the glass is to be used for outside facings or for self-supporting walls.

A method for coating the cut surfaces of cellular glass with a fluxed glass is described in U. S. patent 2,202,714 by Nash.[22] The rough surface of a cut piece of foam glass may be first covered with crushed clear glass, finer than 40 mesh, to fill the surface pores. An equally finely ground layer of crushed glass (colored glass may be used) mixed with a flux, such as lead borate, is applied over the first layer. Then the coated piece is heated to a temperature at which the flux will melt the crushed glass and also penetrate into the surface pores, but at which the foam glass proper is not affected. Of course, one layer may be used instead of two.

Mentioned in a previous section, the surface properties of a foam glass may also be changed by molding the foam glass from layers of different density.[19] Also as mentioned there, it seems obvious to use solid glass as one of the layers whereby it would become possible to make a hollow glass brick which is filled with foam glass. In a similar way Haux, U. S. patent 2,268,251,[32] suggested making a building block from a fired clay shell forming an integral part with an inside of expanded glass.

Reinforcing cellular glass by means of wire mesh close to some or all of the walls is suggested by the British patent 491,907.[41]

Long[1] claims that the strength of foam glass is greatly enhanced by devitrification caused by heating the glass for an extended time to softening temperatures.

As previously mentioned, the sound insulating properties of foam glass are said to be greatly enhanced by partially fracturing the walls of a foam glass by rapidly cooling it to room temperture from 300°F. This process is subject matter of U. S. patent 2,237,032 by Haux.[26]

The following patents have been brought to the writer's attention just before this article is going into press.

U. S. patent 1,471,421 of October 23, 1923 (Dec. 16, 1919) describes a process for the production of foam slag according to which the molten slag is mixed at 1400°C. in a container with water and gas, the addition of water being adjusted so as to bring the temperature down to 1000°C. The thus formed foam slag is then withdrawn and cooled in suitable molds. U. S. patent 1,458,858 of June 12, 1923 (May 15, 1920) deals with a process for rolling foam slag as prepared according to the preceding patent into thin sheets. The foamy melt having a temperature of 1000°C. is rapidly cooled to 800°C. between water cooled rollers and rolled into a sheet of about 5 mm thickness, then fed into molds and solidified.

The manufacture of sponge glass, a glass having inter-

(*Continued on page* 351)

INVENTIONS AND INVENTORS

A Summary of United States Patents of Interest to the Glass Industry Issued During July

Compositions

Frank L. Jones of the Bausch & Lomb Optical Co., Rochester, N. Y., received patent 2,290,911 for optical units made by grinding and polishing to final form a lens made of lead or barium glass, and then heating it in contact with a fused salt of sodium or potassium. This results in improved restistance to staining and corrosion due to the replacement of the lead or barium in the glass surface layers by the sodium or potash.

A vitreous dielectric material for condense s consisting substantially of a potassium lead silicate in the field of stability of the compound $K_2O.4PbO.8SiO_2$ was patented by Stanley O. Dorst of North Adams, Mass. This is patent 2,290,947 assigned to the Sprague Specialties Co.

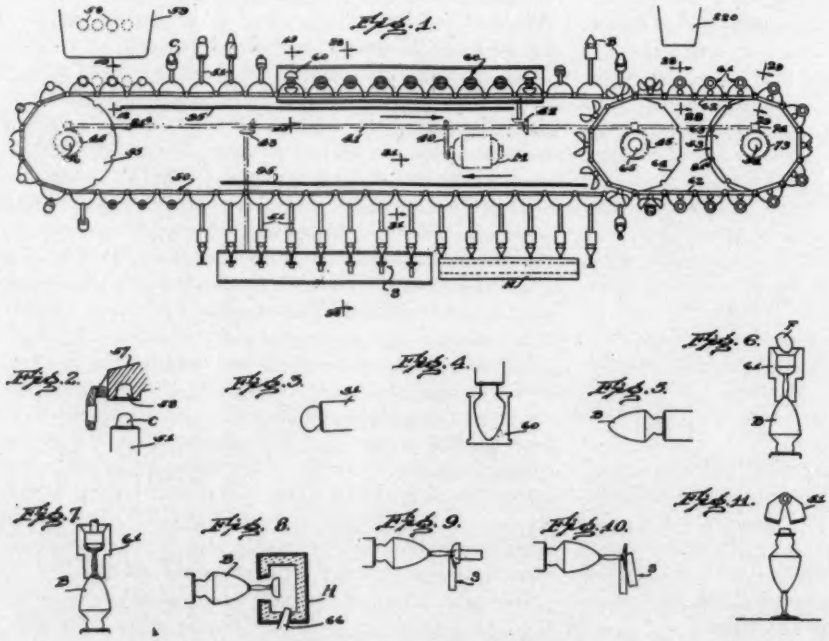
Feeding, Forming & Shaping

The molding of footed tumblers and stemware involves so many separate steps that they are made most largely by hand methods, or in a series of separate machines with the stems and bowls formed in different apparatus. In patent 2,289,999 Harold R. Schutz of Toledo, Ohio (Libbey Glass Co.), describes a machine in which all operations are performed in a single continuous machine. The invention can be understood by referring to Figs. 1 to 11, in which Fig. 1 shows a schematic plan view of the machine, while the other drawings illustrate successive forming steps. In Fig. 1 a continuous spindle-bearing mechanism which moves clock-wise receives charges of glass by suction from a gathering tank 59 at the upper left. The charges C are dropped two at a time onto spindles 51 (Figs. 1 and 2) which serve as holders on which the blanks are held throughout the entire development of the tumbler.

Each spindle as it advances beyond the gathering zone is inverted to a depending position while the blank is being developed in the open (Fig. 3). The inverted blank is received in a blow mold 60 (Figs. 1 and 4) in which it is blown to form the bowl B of the tumbler. The finishing molds are mounted to travel on an endless conveyor and move in synchronism with the spindles. The gathering and developing of the blanks and blowing thereof in the finishing molds 60 corresponds in general to the operations of manufacturing tumblers by a machine such as disclosed in the patent to Kadow, 1,527,556, now commonly known as the Westlake machine.

Each spindle, carrying a blank, after it has been blown in the finishing mold to form a bowl B, is reinverted (Figs. 1 and 5) and then brought into register with a stem and foot-forming mold 61. Mold units 62 (at the right in Fig. 1), each comprising a mold 61 and co-operating mechanism, are connected to form an endless chain conveyor. When a mold 61 is brought into register with a bowl B (see Fig. 6) a gob F is dropped into the mold and thereafter pressed in the mold to form a stem and foot, and at the same time to weld the stem to the bowl (Fig. 7). This completes the formation of the tumbler.

The mold 61 is then opened and the spindle with the molded tumbler supported thereon is swung outward to horizontal position and while in this position advanced along a preheating chamber H (Figs. 1 and 8) with the foot extended into the chamber where it is reheated and softened for final shaping. After this heating each foot



Figs. 1 to 11. 2,289,999: Schutz. Continuous machine for competely forming and finishing footed tumblers.

is reshaped to its final form by a foot straightening or reshaping mechanism S (Figs. 1, 9 and 10). The reshaping devices are connected to form an endless chain which advances in synchronism with the spindles. After the foot reshaping operation the completed article is released from the spindle and thereby discharged from the machine.

Hartford-Empire Co. received two forming machine patents: 2,289,046 granted to George E. Rowe of Wethersfield, Conn., and 2,290,798 granted to Walter K. Berthold of Rockville, Conn. Rowe's invention is a method and apparatus for making containers on a modified Hartford I. S. machine. He avoids the prior practices wherein the charge is allowed to come to rest at some stage in the blank mold, allowing the skin surface to become chilled. In each of the several procedures the charge is continuously in motion through and after its period of delivery by the feeder until the charge is actually pressed into a parison of the desired shape. For example, the charge in falling into the blank mold is checked in its fall by striking the pointed dome of a retracted plunger; the glass deforms to flow slowly downward over the plunger, but before motion ceases the plunger moves upward to press the charge into a parison and to give it good heat extracting contact with all portions of the mold walls at the same time. Mr. Berthold's patent covers a two-head settle blow unit which has a spring mechanism to allow them to become seated on blank molds at slightly different levels.

Fig. 12 shows the method by which Purling A. Bleakley of The Bleakley Corp., Toledo, Ohio, proposes to seal the two halves of glass blocks together in patent 2,290,088. The blocks, made with a groove and over-

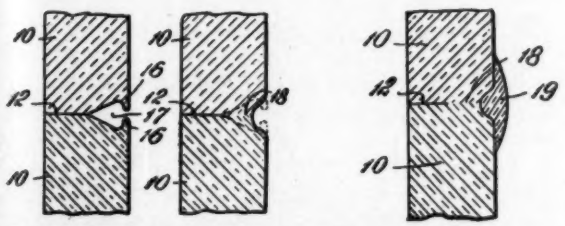


Fig. 12. 2,290,088: Bleakley. Overhanging tips on the edges of glass block helf-sections are fused to form a seal, which is then covered with another sealing substance.

hanging tips 16 are heated by a flame to cause the lips to fuse and run into the groove to form a partial seal. The job is completed by spraying molten glass or another sealing medium 19 over the joint.

A group of Owens-Illinois inventors, Randolph H. Barnard, Frank T. Nesbitt, and Carl W. Schreiber of Toledo, and Joseph P. Benoit and John E. McLaughlin of Alton, Ill., obtained patent 2,290,012 for a suction-fed tumbler machine of the chain type. The gathering molds carried by a chain conveyor deliver their charges to spindles, also carried on an endless conveyor. The blanks carried on the spindles may be partially developed in intermediate molds traveling with the spindles. Then the blanks are transferred to finishing molds in which the articles are blown to final form.

In another Owens-Illinois patent, 2,290,131, Charles B. Smith and Albert G. Lauck of Alton, provided a

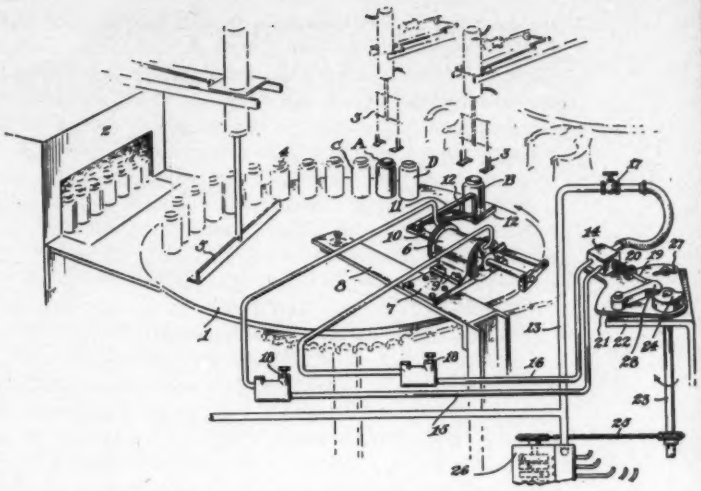


Fig. 13. 2,284,766: Posten. Lehr loading device.

safety device for a motor driven forming machine which will shut off the current supply to the motor and stop the machine when the mold closing mechanism fails to operate due to obstruction or other causes.

Patent 2,292,580 granted to Louis Poglein of Jeannette, Pa. (McKee Glass Co.), concerns a removable center mold insert. The same inventor received patent 2,289,037 for a household utensil consisting of a lid and bottom portion which fit together by tongue and groove projections which also form the handles.

Patent 2,290,917 granted to Charles V. Smith of Dayton (Univis Lens Co.) describes a lens forming press, and particularly the die structure.

Miscellaneous Processes

Fig. 13 shows a lehr loading device invented by Carl F. Posten of Zanesville (Hazel-Atlas Glass Co.) and described in patent 2,284,766.* When containers are placed on the round table they are necessarily rather widely spaced due to the spacing of the molds, and must be brought more closely together before they are carried into position in front of the lehr. In operation, two jars are simultaneously delivered to the rotating table 1, from separate molds of a glass forming machine, by the two separate take-out devices 3. These jars, when delivered to the table, are necessarily too widely spaced for delivery to the lehr 2. The two jars last delivered are shown in heavier lines and are referred to by letters A and B, and the two jars delivered to the table by the previous operation of the take-out devices, are referred to by letters C and D. When the articles are delivered, air is admitted to the rear end of the cylinder 6 to move the pusher 12 forward, and thereby move the jar B forward relative to the table 1, while all the jars are continuously being carried forward with the table.

The jar B is not moved forward to a position adjacent the jar D which was delivered in the previous operation, but is only moved forward sufficiently to leave a space large enough for the placing of another jar between D and B upon the next delivery of two jars by the take-out mechanism. In other words, the jar B will be moved forward so that it is spaced from D about the same distance that is shown between the jars C and D, and when

the take-out devices next operate, the forward jar will be placed between the jars D and B, and the rearward jar will be placed behind the jar B, ready to be moved forward by the pusher 12. By this relatively simple mechanism it is possible simultaneously to deliver to a rotating table two glass articles improperly spaced for delivery to the lehr, and while the table rotates to position the articles in a line and spaced the exact distance required, so that as the line passes across the front of the lehr, the articles are ready to be swept into it by the periodical operation of the pusher bar 5.

Floyd A. Firestone of Ann Arbor, Mich., has assigned to Owens-Illinois Glass Co. his patent 2,285,151* for an apparatus for quickly measuring the capacity of a container by the pressure change when a measured volume of air is released into it. Firestone has extended this familiar principle by providing an oscillating flow into and out of the test container and the measured supply container at a frequency of roughly 20 cycles per second, so that it is practical to measure the difference in the pressure increments by means of a pressure microphone and amplifier such as are used in acoustical investigations. In applying this principle commercially to measuring the capacities of bottles, an accuracy of 0.1 per cent is said to be readily obtainable. The acoustical mobility theory is based on a mathematical background which Firestone presented in the Journal of Applied Physics, June 1938, page 373-387.

Three patents assigned to Hygrade Sylvania Corp. and involving the manufacture of fluorescent or luminescent lamps were 2,289,354 to Roland M. Gardner of Swampscott, Mass., 2,290,837 to Wm. P. Stuckert of Marblehead, Mass., and 2,290,186 to Geo. E. Holman of Melrose, and Ezio T. Cassellini of Salem, Mass. The Gardner patent describes an oven for baking internally coated tubing; the Stuckert patent concerns an apparatus applied to the Danner tube machine for severing the tubing into desired lengths; the Melrose-Cassellini patent covers a glass electric discharge tube filled with mercury vapor and an inert gas, and having a particular luminescent coating.

In another lamp process patent Ray A. Hinkley and Edmund H. Wellech of Corning describe a method of assembling lamp stem parts (2,290,050, Corning Glass Works). Hinkley and Walter C. Weber received patent 2,290,051 for an apparatus capable of doing precision grinding to desired contours.

In tempering glass articles to increase their strength Donald W. Mueller of West Hartford, Conn. (Hartford-Empire Co.), in patent 2,290,763 does not heat them so high as earlier practice is said to have taught. Instead he brings them to a temperature which is just past the midway point of the tempering range before cooling them rapidly to produce the desired condition of temper.

Sheet and Plate Glass

Fig. 14 shows the apparatus disclosed by John Wilson of Birmingham, England (The American Security Co.), in patent 2,291,127 for producing tempered glass sheets. The inventor states that the processes of annealing, cooling and reheating are avoided by his process which involves cutting a drawn or rolled sheet while still plastic, and then cooling the units rapidly to produce a temper. The glass is cut into sheets by the use of stamping dies which contain metal plates to cool the sheets by their own coldness or by water cooling. As shown in Fig. 14 the upwardly drawn glass 1 is cut into sheets by pairs of water chilled dies 9a; when these dies separate, the sheets are retained by the right hand sections and are deposited onto a support 13 at the right; the dies are cooled by water sprays 14.

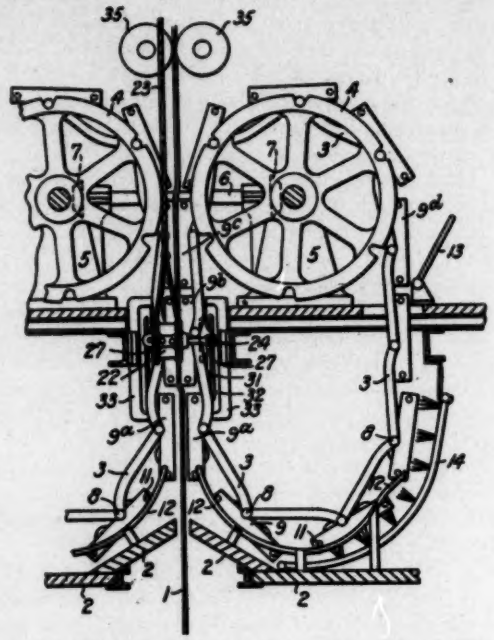


Fig. 14. 2,291,127: Wilson. In making tempered sheets, newly drawn glass is drawn upward through a machine which cuts out sections by means of pairs of stamping dies which are water cooled so as to impart the desired temper. The tempered sheets are removed at 13.

Three patents issued by Libbey-Owens-Ford Glass Co. are 2,289,615 to Carl B. Williams, Jr., of Toledo, 2,289,634 to Walter G. Dieter of Parkersburg, and 2,289,718 to Andrew W. Moore of Toledo. The first of these concerns apparatus for folding and laying plastic sheeting, the second covers a structural building unit, and the third describes a hand cutter for glass sheets.

Fig. 15 illustrates the apparatus for making wire glass which is described in patent 2,291,549 granted to Paul F. Gutmann of St. Louis (Mississippi Glass Co.). The glass flows from a forehearth between a lip 22 and one of a pair of rolls, and is formed between these two rolls which are maintained on about the same horizontal level. The wire mesh is introduced from above the junction of the rolls. Since the amount of glass flowing to the rolls must be rigidly controlled there are means for adjusting the right-hand roll to alter its clearance with the forehearth lip, without altering the size of the forming pass between the rolls.

The composition of the plastic layers in laminated safety glass was the subject of patents 2,290,193 to Arnold Kirkpatrick of Webster Groves, Mo. (Monsanto Chemical Co.), and 2,289,792 to Carl J. Malm and Gerald J. Clarke of Rochester, N. Y. (Eastman Kodak Co.).

Apparatus for polishing plate glass in strip form by multiple discs operating on both sides of the sheet simultaneously, is described in patent 2,285,318 issued

to Frederic B. Waldron of Prescot, England (Pilkington Bros., Ltd.).

Patent 2,291,451 granted to Walker H. Craig and George I. Finley, Jr., of Crystal City, Mo. (Pittsburgh Plate Glass Co.), concerns a method of trimming glass sheets (as in cutting wind-shields) which consists in scoring the sheet glass, supporting the sheet against a yielding flat surface and applying sufficient pressure pneumatically over the area of the sheet to snap the glass along the scoring.

In 2,287,598, the latest Polaroid Corp. patent, Chas. H. Brown of Baldwin, N. Y., outlined methods of making a polarized glass lens consisting of glass with embedded electrically conducting wires. Each wire must have a diameter not exceeding 0.2 microns and it is stated that there should be at least 80,000 of such wires per inch of lens. To meet this seemingly impossible specification, Brown describes several manufacturing processes. In one of these, wires are arranged in equally spaced parallel fashion in a suitable frame, and powdered glass is then sifted over them. The unit is heated to melt the glass, and both the wires and the glass are stretched to elongate the wire. This reduces their diameter and brings them closer together. The elongated glass is cut into sections and the process is repeated numerous times until the desired thinness and closeness of wires is obtained.

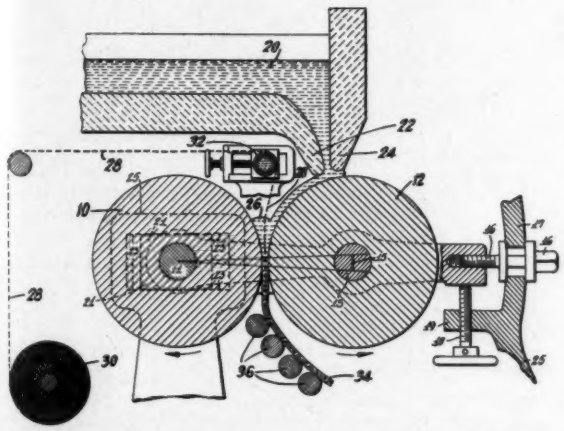


Fig. 15. 2,291,549; Gutmann. A continuous wire glass machine in which the right hand roll can be moved vertically to control the amount of glass fed to the shaping rolls without altering the forming pass between the rolls.

Glass Wool and Fiber

Patent 2,291,289 granted to Games Slayter and John H. Thomas of the Owens-Corning Fiberglas Corp., Newark, Ohio, discloses a method of drawing glass fibers from a metal bushing which constitutes the lower end of the usual remelting furnace. The fibers are drawn by means of blowers located mostly above the level of the orifices and having jets directed towards the orifices to draw and cool the fibers.

*Issued in June but omitted from last month's Inventions and Inventors.

• The General Sales Offices of the Michigan Alkali Company have recently been moved to Wyandotte, Michigan P. O. Drawer 472) from the Ford Building, Detroit.

DONALD SHARP AWARDED DEGREE

Donald E. Sharp, assistant research director of the Hartford-Empire Company, has been awarded the Professional Degree of Ceramic Engineer by Alfred University.

Mr. Sharp, outstanding in the field of glass technology, started his career in the physical laboratories of the Corning Glass Works. He later served as assistant in the physics department of the University of Wisconsin and then in the ceramics department of the Bureau of Standards. In 1925 he purchased the optical glass plant of the Spencer Lens Company in Hamburg, New York, four years later organizing the Bailey & Sharp Company of which he was president and general manager until the entire staff was absorbed by the Hartford-Empire Company in 1937.

CAUSTIC SODA AND SODA ASH PERMITTED UNLIMITED STORAGE

The Director General for Operations has announced that unlimited storage by industrial users of caustic soda and soda ash is now permitted. Increasing supplies of these materials, used in the manufacture of aluminum and other non-ferrous metals, glass, soap, textiles, leather, dyes, petroleum, paper and other products, make it advisable that wide distribution be made now against future demand.

GLASS DIVISION MEETING

The Summer Meeting of the Glass Division of the American Ceramic Society will be held at the Seaview Country Club, Absecon, New Jersey, on September 18, 19 and 20. J. F. Greene, in charge of papers, reports that a program of papers of a practical nature is being planned and which should be of particular interest to plant executives. Technical meetings are scheduled for the afternoon of Friday, the 18th. and Saturday morning. Social acitvities will include a golf tournament Saturday afternoon.

The Seaview Country Club affords an indoor salt water swimming pool among other attractions. Rates are on the European Plan. All Atlantic City trains will stop at Absecon by notifying the conductor. Club busses will meet trains and private bus service to and from Atlantic City will be available.

• E. H. Anthes, manager of the New York Branch of the Bausch & Lomb Optical Company since 1933, died on August 3, 1942 following a short illness. He had been associated with the company for 33 years. Prior to coming to the United States he was associate manager of the London Office. He was widely known in educational and industrial circles as an authority on the use and history of the microscope.

WANTED: Man with thorough and long experience in the manufacture of thermos bottles. Plant located in Mexico. Reply giving full information, experience, age and training to Box 53, The Glass Industry, 55 West 42nd Street, New York, N. Y.

Research Digest

Practical Interpretations of Glass Technology

Murgatroyd, Journal of the Society of Glass Technology, February, 1942, who is responsible for that part of the glass technologist's anatomy which is now so famous, i. e., the "Murgatroyd belt," once again takes a routine subject and places it on a more scientific basis.

Nearly all container manufacturers make routine thermal shock tests on their ware as a matter of course. The author's main point is, that if a mere numerical expression of the result is all that is obtained from such tests, then full advantage is not being taken of the thermal shock test. If in addition to the percentage broken result, information is also obtained on the cause of failure through an examination of the broken containers, the knowledge gained will enable one to correct the defect in manufacture which gives rise to it. This is an excellent point for those who use the "all pass" type of thermal shock test to keep in mind. With the "all pass" type of test it is impossible to use quality control methods or to pick up in advance trends which may be acting to lower the "all pass" level.

The examination procedure employs a deductive process based on (1) the knowledge of the location, direction, and intensity of the stresses in the container under the test conditions; (2) on the character of the fracture surfaces to determine the point of origin of the fracture; (3) on the various types of surface flow; and (4) on the state of homogeneity and annealing of the glass.

It was shown that the requirements of item 1 may be found for any type of container by the use of a very simple procedure. For example, in the case of a container in which failure is caused by tension on the outside surface of the walls, diamond scratches are made at several different positions on this surface and a progressive thermal shock test then made. Examination of the failures as the severity of the thermal shock is increased will indicate the zones where stress "concentration" occurs. It is interesting to note that the experimental data obtained by the author again confirms the vulnerability of the "Murgatroyd belt."

Items 2 and 3 follow the basic work of Preston on glass fractures and emphasizes the importance of determining the origin of the crack if the cause of the fracture is to be discovered.

In the discussion of item 4 the ring section method of examining cord as devised by Swicker is recommended as a necessary adjunct to the thermal shock test, especially in those cases where the inhomogeneity causes tension to appear in the outer layer. In the discussion on the location of the ring section samples which should be taken, it may have been well if it had also been pointed out that vertical sections, which consist of both the base and sidewalls, often afford valuable clues to baffle mark breakage as such sections allow the examination of both the shape of the baffle mark and the concentration of both stress and cords at this point.

The techniques described in these various items are reduced to a table of procedure similar to those used in qualitative chemical analysis. This "Analytical Table" is quite novel. In addition to outlining the examinaton procedure in detail it also discusses the cause of the defects and their remedies. The table is reproduced below:

Analytical Table for Thermal Endurance Test Breakage.

1. *Examine the Annealing Standard.*

If this is normal, proceed to

2. *Examine for Homogeneity and Fracture Limits.*

A. The containers are shattered. Examine homogeneity.

Repeat thermal endurance test with lower temperature difference to prevent shattering.

Proceed with examination as in B 2.

B. The containers are not shattered. Mark fracture limits and complete fractures to expose surfaces for inspection.

3. *Examine for Type and Origin of Fracture.*

A. The fractures are smooth-faced.

Examine outer edges for kinks due to small bruises, or roughening due to crizzles (use magnification if necessary.)

B. The fracture surfaces show rib-marks.

Trace origin as closely as possible and look for stones, "drops," bruises, or evidence of crizzles (roughened outer edge of fracture.)

4. *Examine for Cause of Weakness and Procedure to Remove it.*

According to the type of origin of fracture proceed to consider the following possible causes:

A. *Stones, "Drops," etc.*

Attention to furnace, pot, forehearth, etc.

B. *Bruises.*

If regular (all located in same zone of container), examine mechanical handling equipment at stage where it can make contact with the container in the zone indicated. If irregular, and frequently away from maximum stress zone, inhomogeneity indicated. If inhomogeneity not found, examine handling in sorting, packing, or similar operations.

C. **Crizzles in Body.*

Confirm presence in zone indicated by examining other ware from same manufacture. If crizzles not obvious in this ware, warm the zone and blow cold air on it to open up any crizzles existing. Examine mould or handling equipment where it makes contact with the zone indicated.

D. *Crizzles in Base.*

Crizzles in a radial direction indicate hot containers meeting a cold conveyor, etc. Crizzles in a circumferential direction, particularly in the region between 50 per cent. and 80 per cent. of the container diameter, are most probably due to deep baffle, valve, or shear marks.

Selenium Black Glass

With coloring materials such as manganese and cobalt on the critical list and therefore unavailable as colorants, those interested in the manufacture of black glasses may

*Ed. note: The term "crizzles" has the same meaning as the term "checks."

find the paper by Austin and Sullivan (Jour. American Ceramic Society, March, 1942) of interest. By meeting a soda-lime-silica glass under reducing conditions or with a reducing agent in the batch, black glasses were obtained with only minor additions of selenium along with cobalt, nickel or iron. While the best black glass was obtained with less than 0.2% selenium and less than 0.1% cobalt (as carbonate) a glass which was on the brownish-black side was obtained when ironoxide was substituted for the cobalt. This selenium-ironoxide combination as a colorant for black glass may bear additional investigation as to its possibilities.

Effect of Ironoxide on Melting of Glass

Window and plate glass manufacturers have long known that improvement in color when obtained by lowering the iron content of the glass results in either an increased heat input to the furnace or a lower output of glass. In fact one large manufacturer of such glasses intentionally adds small amounts of ironoxide to the batch for the sole purpose of increasing the output without increasing the fuel requirements. Shute and Badger (Jour. American Ceramic Society, August, 1942) have investigated this phenomena and have found that as the iron content of the glass is increased (0.035% to 1.035%) the temperature gradient in the meet is rapidly increased. This greater drop in temperature as compared with low iron glass produces cooler tank bottoms and a more shallow melting tank is the result. If the amount of iron is increased too greatly, however, the excessive gradient so produced may produce a decrease in glass quality by making the glass stream too shallow. (This is analogous to emerald green chromium glass experience.) There seems to be some possibility that similar small increases of iron to optically dense glasses such as cobalt blues, in which the iron color can be masked, may result in the same phenomena.

It was also found that small amounts of ironoxide exert a chemical fluxing action if melting is carried out at a comparatively low temperature such as 1200°C. (This fluxing action may take place in a hotter furnace especially if the batch is introduced in the form of piles rather than a thin sheet. In the form of a pile the interior of the pile is much lower in temperature than the exterior and the ironoxide fluxing action may well start here.)

OPTICAL SOCIETY ANNUAL MEETING OCTOBER 30 AND 31

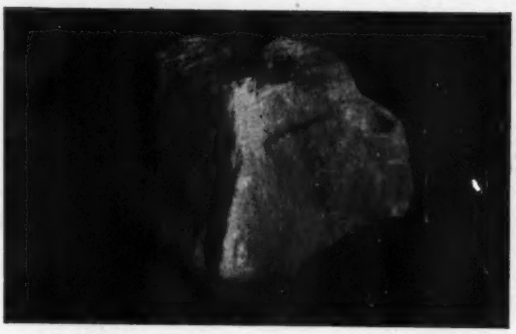
The 27th annual meeting of the Optical Society of America will be held at the Hotel Pennsylvania, New York City, on October 30 and 31. The date of the meeting has been planned to coincide with meetings of the American Mathematical Society and the Society of Rheology and to follow the meeting of the Society of Motion Picture Engineers.

A symposium of invited papers on "Optical Instruments" and on "Mathematics in the Field of Optics" will be held the first day together with the luncheon and dinner. The following day contributed papers will be presented. Abstracts of contributed papers must be sent in by members to the Secretary by Sept. 28. Nonmembers are invited to attend the meetings.

Now...

Lime or Limestone (dolomite) is essential in

MAGNESIUM METAL



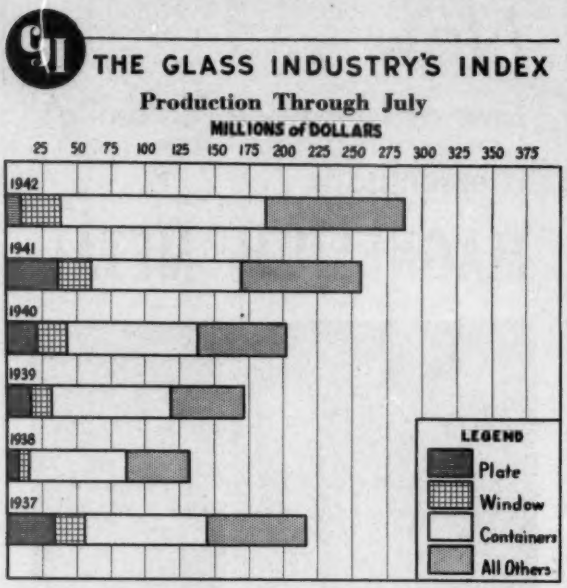
Dolomite Lime and Limestone are earning another service stripe by serving Uncle Sam's newest production division . . . the making of MAGNESIUM METAL.

Magnesium Metal is strong, light and durable and is particularly adaptable to the structural shapes and castings necessary in the building of planes and ships.

The same fine qualities that have made Banner Lime so essential to Building, Steel, Agriculture and Glass Making have qualified Banner Lime or Limestone (dolomite) as an essential in the making of MAGNESIUM METAL. National Mortar and Supply Co., Pittsburgh, Pa.

Since 1907 A Good Company To Do Business With

CURRENT STATISTICAL POSITION OF GLASS



During July activity in the glass industry continued to decline, production, employment and payrolls were below the previous year's level. According to the July Production Index output totalled $36,000,000 as compared to $39,000,000 in July, 1941; the first seven months of this year glass production amounted to $286,000,000 or 12 per cent above last year's corresponding total.

Plate glass production during July totalled 4,193,605 square feet according to the Plate Glass Manufacturers of America. This was 15 per cent less than the previous month's volume and was 68 per cent below the July, 1941, level. During the first seven months of this year plate glass output amounted to 39,108,000 square feet or 65 per cent less than last year's corresponding figure.

Window glass production during July totalled 1,273,803 boxes which represented 78.5 per cent of the industry's total capacity. This was 4 per cent greater than the previous month's total and about equalled the July, 1941, volume. The cumulative total for the January-July period was reported to be 10,376,000 boxes or 8 per cent greater than last year.

Glass container production during July totalled 5,943,533 gross according to the Glass container Association of America. This represented a decline of 12 per cent from the previous month and 10 per cent from July, 1941. During the first 7 months of 1942 a total of 46,439,936 gross were produced—23 per cent more than in 1941's comparable period.

Shipments of glass containers during July amounted to 6,333,374 gross which was slightly below the June, 1942, and July, 1941, totals. Compared with July, 1941, pressure and non-pressure ware dropped 39 per cent, narrow neck food containers 29 per cent, general purpose ware 18 per cent, domestic jelly glasses 56 per cent, medicinal and toilet ware 15 per cent and pressed food ware 8 per cent; increases were reported for beer bottles (up 69 per cent), wide mouth food containers (up 16 per cent), milk bottles (up 7 per cent), liquor ware (up 3 per cent), and domestic fruit jars (up 2 per cent). During the first 7 months of this year shipments increased 18 per cent over last year to 45,614,915 gross. All lines, with the exception of pressure and non-pressure ware, participated in these gains. Largest increases were reported for beer bottles (117 per cent), domestic fruit jars (33 per cent), narrow neck food containers (31 per cent) and wide mouth food containers (24 per cent); gains in other lines ranged from 4 to 9 per cent.

Inventories of glass containers in the hands of manufacturers on July 31, 1942, totalled 9,523,148 gross, or 17 per cent higher than last year's corresponding figure. Stocks of all types of containers were higher with the exception of pressed food ware, pressure and non-pressure ware, beer bottles and domestic jelly glasses.

Miscellaneous Glass Products manufactured during July were valued at $14,000,000; this compared with $13,000,000 in July, 1941. During the first 7 months of 1942 production in this branch of the industry totalled $108,000,000, which was 29 per cent greater than last year's comparable figure.

According to a preliminary report of the Bureau of Census, 11 firms reported sales of illuminating glass ware totalling $500,000 during July; this was 25 per cent less than the July, 1941, total and was 10 per cent under the June, 1942, volume.

Manufacturers' sales of machine-made table, kitchen and household glassware during July were reported to

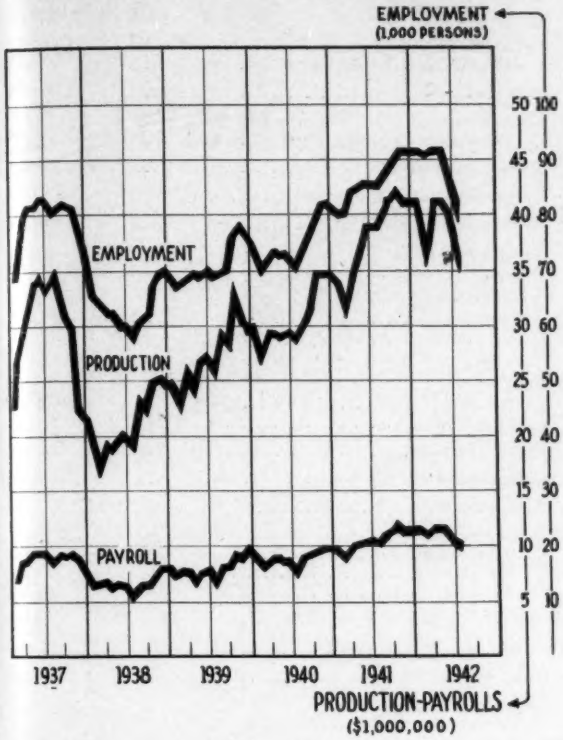
CURRENT GLASS CONTAINER STATISTICS

(ALL FIGURES ARE IN GROSS)

Classifications	Production		Shipments		End of Month Stocks	
	July, 1942	*July, 1941*	*July, 1942*	*July, 1941*	*July, 1942*	*July,1941*
Food Containers (Narrow neck, wide mouth, and pressed)	1,995,215	1,983,143	2,000,087	1,861,718	2,517,126	1,972,432
Pressure and Non-Pressure Ware	350,277	606,191	416,049	693,517	388,821	478,846
Beer Bottles	834,297	439,094	836,660	492,703	411,557	640,095
Liquor Ware	707,662	882,246	853,061	840,839	1,449,469	1,346,816
Medicinal and Toilet Ware	1,285,735	1,559,890	1,378,972	1,608,216	3,223,884	2,654,959
General Purpose	335,369	384,929	328,331	400,649	629,917	465,420
Milk Bottles	283,716	293,427	290,320	277,004	350,152	295,015
Fruit and Jelly	129,934	147,914	194,881	200,190	518,877	282,880
All Other	23,328	27,978	30,013	25,131	38,343	39,806
Total Industry	5,945,535	6,324,812	6,333,374	6,399,967	9,528,146	8,176,269

THE GLASS INDUSTRY'S INDEX

Monthly Trends Through July, 1942



have totalled 2,397,054 dozens as compared to 2,903,142 dozens in July, 1941. July's statistics of automatic tumblers were not available for inclusion in this issue but will be reported with the August figures next month.

Employment and Payrolls: Employment in the glass industry during July totalled 81,000 persons as compared to 85,000 in June and 86,000 in July, 1941.

Payrolls in the glass industry during July amounted to $11,500,000 as compared to $12,000,000 in June and $11,000,000 in July, 1941. During the first 7 months of 1942 glass manufacturers paid out about $84,500,000 in wages as compared to $72,500,000 last year.

FOAM GLASS (*Continued from page* 343)

communicating pores, is the subject of the following patents. U. S. patent 2,209,163 of July 23, 1940 (July 8, 1939) by G. Kaloustian (to Cobrecite Co.) describes such a process according to which a silicious material is mixed with an alkaline flux and an inert material having a higher melting point than the silicious material and which later can be removed from the mixture. The mixture is heated so as to fuse the silicious particles by means of the flux, whereafter the inert material is removed to obtain the desired sponge structure. U. S. patent 2,209,170 of same date by H. S. Nevin and Kaloustian (to Cobrecite Co.) deals with a similar process according to which, e.g., 5 to 9 parts volcanic glass, 1 part water and 1 part alka-

(*Continued on page* 354)

ALKALIES

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Perhaps you as a glass maker, do not realize that alkalies are a factor in nearly all industries—*practically every one of which is on a war time production basis.*

This explains why, even though Solvay is America's largest producer of alkalies, it cannot always supply full alkali requirements of the many Solvay customers who manufacture other than war materials.

Yet, as fast as changeovers can possibly be made, we are *increasing* production of important alkalies and related products to meet war time needs. At the same time, it is possible that Solvay Technical Service may prove helpful in finding a solution to problems arising from material shortages. Inquiries are cordially solicited.

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CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	50.00	55.00
Precipitated material		55.00	60.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)			
Granulated	In bulk, ton	42.50	....
Granulated	In bags, ton	46.00	56.00-61.00
Powdered	In bags, ton	51.00	61.00-66.00
Boric acid (H_3BO_3)			
Granulated	In bulk, ton	96.50	
Granulated	In bags, ton	100.00	111.00-116.00
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07¼
Cryolite ($Na_3Al F_6$) Natural Greenland (Kryolith)	lb.	.03½-.09¾	.10
Synthetic (Artificial)	lb.	No supplies available.	
Feldspar—(published list prices)			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags.			
Fluorspar (CaF_2) domestic, ground, 96-98% (max. SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	34.00	....
In bags	ton	36.40	50.00
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.0900	....
In 5 Ton lots	lb.	....	.0950
Less than 5 Tons	lb.	....	.10
Lime—			
Hydrated($Ca(OH)_2$–MgO) (in paper sacks)	ton	8.50	9.50
Burnt (CaO–MgO) ground, in bulk	ton	7.50	....
Burnt, ground, in paper sacks	ton	9.50	9.50
Burnt, ground, in 191 lb. gross drums Per drum		1.70	1.80
Kiln Dried ($CaCO_3$–$MgCO_3$) 10x30 mesh	ton	2.00	....
Kiln Dried ($CaCO_3$–$MgCO_3$) 16x20 mesh	ton	2.00	....
Nepheline Syenite, f. o. b. shipping point	In bulk, ton	12.00	15.00
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4) in bags	ton	21.00-22.00	28.00-30.00
	in bulk	17.50	
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In Paper bags	Per 100 lb.	1.10	
In Burlap bags	Per 100 lb.	1.15	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls. 95% and 97%	Per 100 lb.	....	3.00-3.40
Bulk	Per 100 lb.	1.35	3.60-4.00
200 lb. bags		1.4675	....
100 lb. bags		1.5025	....

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	.031-.034	.045
Aluminum oxide (Al_2O_3)		.07	.09
Antimony oxide (Sb_2O_3)	lb.	.15	.15½-.16½
Arsenic			
Glassmakers	lb.	.01¼	.04¾
Regular refined white	lb.	.04	.04½
Arsenic trioxide (As_2O_3) (dense white) 99%			
In barrels		.04-.04¼	.04½-.04¾
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	Open price.
Pyrophyllite (20% Al_2O_3)	ton	10.00	13.00
Sodium fluosilicate (Na_2SiF_6)	lb.	.07½	.09
Tin Oxide (SnO_2) in bbls.	lb.	....	Open price.
Titanium Oxide (ceramic grade)			
In bags	lb.	.11½	....
In barrels	lb.	.14¾	....
Zinc Oxide (ZnO)			
American process, bags	lb.	.07¼	.07½
White Seal, 150 lb. bbls.	lb.	.09¾	.10
Green Seal, bags	lb.	.09	.09¼
Domestic White Seal, bags	lb.	.09½	.09¾
Red Seal, bags	lb.	.08½	.08¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.05¾	.06

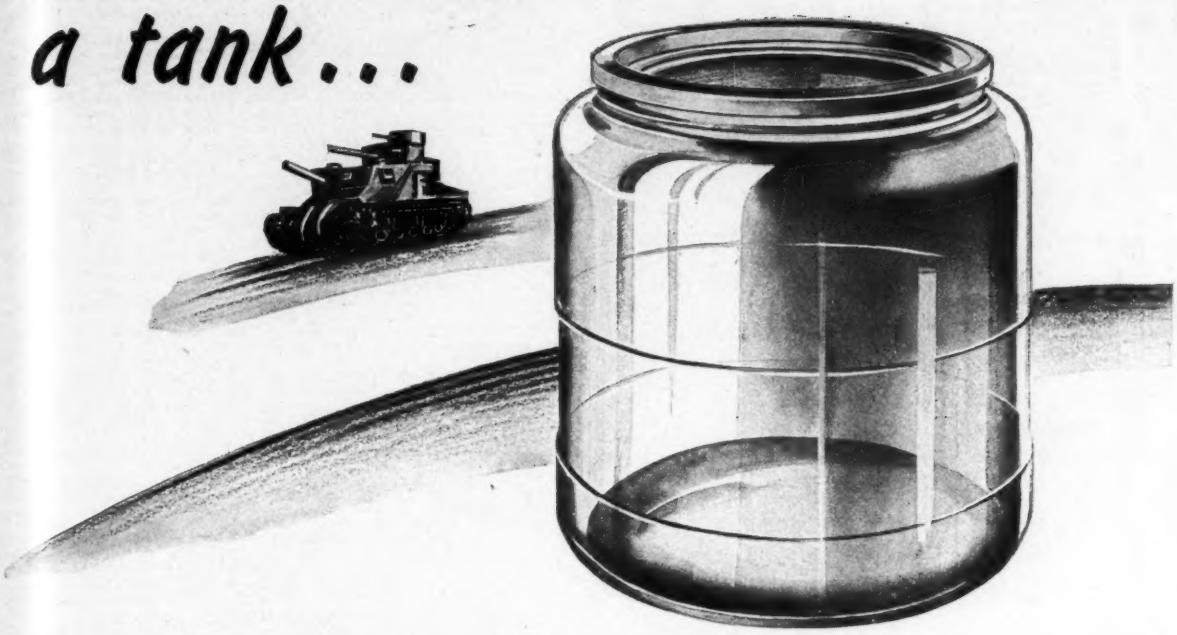
Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.40-1.60
(Commercial, 25% Selenium)	lb.	....	.85
Cadmium sulphide (CdS)	lb.	....	1.10-1.15
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls.	lb.	....	.25-.28
Chromite (99% through 200 mesh)	ton	58.25	64.75
Chromite ore (air floated)	ton	58.25	64.75
Cobalt oxide (Co_2O_3)			
In bbls.	350 lbs. or more, lb.	....	1.84
	Less than 350 lbs., lb.	....	1.94
Copper oxide—			
Red (Cu_2O)	lb.	....	.20-.22
Black (CuO)	lb.	....	.19-.22½
Black prepared	lb.	....	Open price.
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.06½-.10
Black (Fe_3O_4)	lb.	....	....
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$) in bbls.	lb.	....	.16
Lithium Carbonate	lb.	....	1.25
Manganese, Black Oxide African			
In Paper bags	ton	70.00	78.00
In Burlap bags	ton	71.75	79.75
In Casks	ton	74.00	82.00
Neodymium oxalate, 50 lb. drums	lb.	....	4.00
Nickel oxide (Ni_2O_3), black	lb.	....	.34-.40
Nickel monoxide (NiO), green	lb.	....	.35-.37
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals and Granular	lb.	.09½	.09¾-.10
Powdered	lb.	....	.10¼-.10½
Potassium Chromate (K_2CrO_4) 100 lb. kegs.	lb.	....	.27
Powder blue	lb.	....	.21-.25
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) in 100 lb. lots	lb.	....	1.75
In lesser quantities	lb.	....	1.85
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.07¼	.07½-.07¾
Sodium chromate (Na_2CrO_7) Anhydrous	lb.	.08½	.08¾-.09½
Sodium selenite (Na_2SeO_3)	lb.	....	1.50-1.65
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.65
Yellow	lb.	....	1.65
Sulphur (S)—			
Flowers, in bbls.	Per 100 lb.	3.40	3.75-4.15
Flowers, in bags	Per 100 lb.	3.05	3.40-3.80
Flour, heavy, in 250 lb. bags	Per 100 lb.	2.95	3.30-3.70
Uranium oxide (UO_2) (black, 96% U_3O_8)			
100 lb. lots. Black	lb.	....	2.55
Yellow orange	lb.	....	1.65

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	.075	.08
Pumice Stone,			
American Ground FFF, FF, F	lb.	.03	.04
0, 0½, ½, 1	lb.	.05¾	.05¾
Putty Powder	lb.	Open price.	
Rotten Stone (Domestic)	lb.	.02¼	.03½
Rouge, Red	lb.	.18	.16
Black	lb.	.15	.18

Not as tough as a tank...



BUT GEARED TO A WARTIME ECONOMY

AN ordinary glass container isn't as impressive or as formidable looking as a 28-ton tank . . . but it's an important item in our war economy. For the increasing use of the glass container is helping release vital tin and steel for war production. Equally important, it is helping to maintain established food habits of 130,000,000 Americans.

Leading glassmakers have long looked to Mathieson Dense Soda Ash for dependable results in every type of glass manufacture. Years of continuous use have convinced them that Mathieson Dense Soda Ash has a uniform, granular composition. They know they can depend upon the ash to be free of oversized particles, dust and other impurities. These properties insure quick, efficient melting . . . help produce finished glassware of uniform quality and durability.

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FOAM GLASS (*Continued from page* 351)

line flux are heated so as to create a bond between the points of contact of the silicious material.

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TOLEDO TRIAL CONCLUDED

(*Continued from page* 334)

acquired or are controlled by Hartford."

Hartford has acquired 317 patents from others, many of them competing patents, Judge Kloeb ruled. He said that frequently the patents were shelved on acquisition and the manufacture of the patented article discontinued. The patents were discarded, he said, to attain control over the industry and eliminate competition.

Owens-Illinois has acquired all the patents in existence in the United States which cover the suction art of automatic manufacture of glassware, he said. Hartford and Owens dominate the art, through their cooperation and close working relationship, he ruled, and have eliminated competition between them. Judge Kloeb charged that the domination is the result of an over-all plan, a scheme devised and pursued to attain domination by means of patent ownership and control.

His opinion said of the alliance: "The entire history of the Owens-Hartford 'partnership,' from its formation in April, 1924, down to the present time, indicates an unholy alliance designed by the parties to attain selfish objectives at the ultimate expense of the public. The primary purpose underlying the alliance was not merely to settle legitimate conflicts, Patent Office interferences or litigation in the courts in the interest of efficient operation of the patents, but the primary purpose was to achieve domination of the industry."

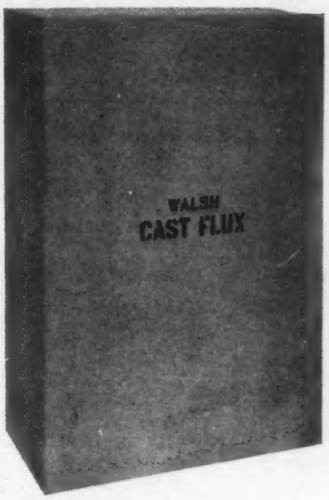
Judge Kloeb said it is impossible today for any individual or concern to engage in the manufacture of glass container ware, with the use of automatic machinery, either gob or suction, without applying to Hartford or Owens. Hartford has consistently followed a policy of refusing licenses to new enterprises and consequently no new concern can have access to the gob feed method of manufacture. No new enterprise can obtain a modern version of the suction automatic process because Owens manufactures its machines only for its own use and refuses to license anyone, the judge charged.

His opinion read further, "In the manufacture, distribution and sale of glass products the fingertip control exercised by Hartford is so complete in its make-up and so efficient in its operation as to make the entire industry now engaged in the manufacture of glass container ware subservient to the desires of Hartford. This is accomplished, of course, by and with the cooperation of Owens in its control of the suction process and its cooperation with Hartford in the control of these concerns engaged in the use of the gob feed process.

"This whole system of control could not be the accidental result of normal growth and expansion, either of a patent holding and development company such as Hartford or of a glassware manufacturing company such as Owens. It is the result of a planned procedure which places in the hands of Hartford the power of life and death over individual units in the industry. It is said that the power to exact royalties is the power to control prices. Certainly the power to control prices rests in the hands of Hartford to increase the license fees and royalties charged its licensees at any time that it desires." This results, Judge Kloeb said, in an increase in the charge to the public for the output of the glass-making machines. Hartford and Owens have so domi-

(*Continued on page* 358)

WALSH CAST-FLUX



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LOW MELTING GLASSES . . .

(*Continued from page* 338)

Ion	Valency	Ionic Size: Size of Oxygen	Deviation in Size	Deviation in Valency
Requirements for Optimum Conditions	4–5	0225–0414		
Ti	4	.49	Too Large	–
Zr	4	.6	Too Large	–
Sn	4	.56	Too Large	–
Al	3	.38	–	Too Low
Be	2	.24	–	Too Low
Zn	2	.5	Too Large	Too Low

Table IV. Deviations from the Requirements of a network former.

2. The network formers which hold the oxygen together (Si^{4+}, P^{5+}).

3. The network modifiers which occur in the interstices of the oxygen structure. (Na^{+}, Ca^{++}).

We have to realize, that almost all other elements can substitute for one of the three constituent types. Many elements which do not fulfill the requirements for a network former exactly can, nevertheless, form a part of the network if these requirements are approximately met.

The possible deviations from the requirements go quite far, both in size and valency. Some examples are given in Table IV, in comparison with the actual requirements of a network former.

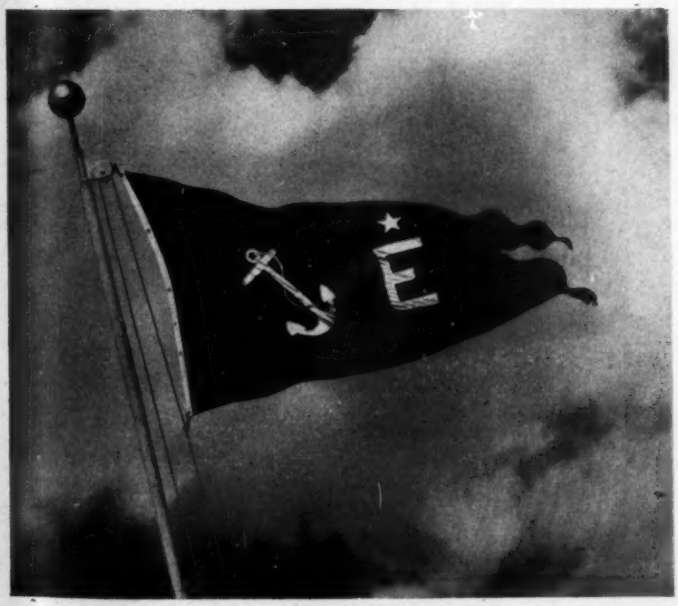
Ions having too low a valency may be induced to assume the position of a network former, if they either are small and, therefore, are to be found near the top of the columns of the periodic system (Al, Be) or if they are the more strongly polarizing elements of the subgroups (Zn, Cd). In crystals, the possibility of the replacement of silicon by aluminum or beryllium in its surrounding of four oxygen has been shown by Machatschki. The Zn^{++} ion has this fourfold coordination in the case of the zinc orthosilicate, Willemite. In the main group of the periodic system Mg^{2+}, although smaller than zinc, but larger than Be^{2+} exhibits sixfold coordination in its orthosilicate (olivine).

Every ion which we introduce in a base glass has to take one of the three typical places, namely, that of oxygen, silicon or sodium. From this consideration we derive the following structural changes leading to a lower melting glass (Table V).

TABLE V

1. Introduction of $B\text{-}O_3$ triangles instead of $Si\text{-}O_4$
2. Increase of the oxygen ratio ($SiO_2 \rightarrow P_2O_5$; $SiO_2 \rightarrow Na_2SiO_3$).
3. Partial replacement of the glass former by one of larger size or lower valencyy, the oxygen ratio being maintained ($Si \rightarrow Ti$, Al).
4. Replacement of a modifier by one of higher potential ($Na \rightarrow Li$) or by a larger number of modifiers ($Na \rightarrow Na + K + Li$).
5. Replacement of oxygen by Monovalent ions ($SiI_2 \rightarrow BeF_2$: addition of F, Cl to silicate glasses).

A New Star Over America



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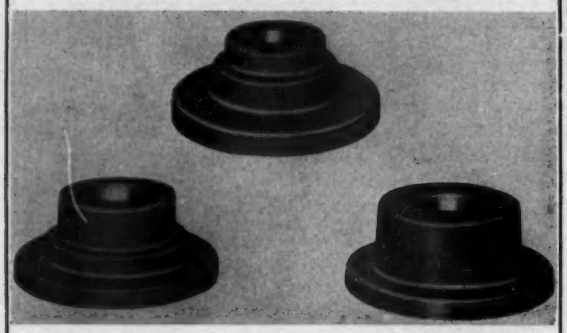

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TOLEDO TRIAL CONCLUDED

(*Continued from page* 355)

nated the industry that prices to the consumer of glassware may be arbitrarily raised beyond all reason.

Judge Kloeb said that a study of the entire record convinced him that there has been a violation of the anti-trust laws, beginning with the Hartford and Empire agreement in 1916, and that the violation was "as deliberate as any that I can find in a review of anti-trust cases."

The first step toward remedying the Hartford situation, Judge Kloeb said, is the appointment of the receiver, Mr. Shanley, under bond of $50,000 and to deny any stay from the appointment. Judge Kloeb said the licensing and lease system used by Hartford was the greatest abuse because it maintained a system of stabilization of the industry and enforced restrictions and conditions far beyond the privileges of the patent grant.

He ruled that any future system for the distribution of automatic machinery must be put on a basis of outright sale at reasonable prices. In addition all the defendants will be required to license anyone, royalty free, in the manufacture of machines embodying these patent rights.

In the future this machinery is to be sold to anyone, including the present licensees of Hartford as well as the remaining outsiders. Newcomers who desire to enter the business of manufacturing shall be sold the necessary equipment, provided they have an eligible credit rating, Judge Kloeb ruled. He said further that all the existing agreements, leases and licenses must be cancelled and any new agreements must be free of restriction and subject to the approval of the court. In the future any manufacturer may produce any item he wants and the machinery now under license will be sold to the present licensees at reasonable rates, Judge Kloeb declared.

The complaint covered acts of the defendants over a period of 25 years. Trial proceedings were begun March 3, 1939 and continued to July 3, 1942, during which time there were 112 days of actual testimony. The record is in excess of 12,000 pages and there are 3,300 exhibits, mostly documentary.

SPECTRAL TRANSMISSION . . .

(*Continued from page* 333)

TABLE IV

Measurement	A	B	C	D
T_1 (% at 2 mm.)	15.0%	22.0%	38.2%	67.0%
T_1	.150	.220	.382	.670
Bt from Table VI	.788	.622	.382	.138
Multiply by 1.5	1.182	.933	.573	.207
T_2 from Table VI	.0605	.1074	.2460	.5715
T_2 (% at 3 mm.)	6.1%	10.7%	24.6%	57.2%

The logarithmic character of Table III will be noted when one attempts to look opposite the figure 1.182 to obtain the corresponding transmission figure. Actually the first integer is dropped, of course, and only the figure 0.182 is looked for in the table. The correspondence of the integer to the "characteristic" of a logarithm is evident at once and indicates that a cipher should be put ahead of the value of T taken from the table.

Graphical Computation

The labor of converting data for different thicknesses may be simplified also by a graphical method utilizing semi-log cross-section paper.

It will be obvious that the equation utilized in the foregoing may be converted to the form:

$$\frac{\log T_2 - \log 0.92}{t_2} = \frac{\log T_1 - \log 0.92}{t_1} = -B$$

or $\log T = \log 0.92 - Bt$ where T is transmission, t is thickness in any suitable unit and B is a constant.

Accordingly, if transmission is plotted against thickness on semi-log paper, the former being plotted on the log scale, and the latter on the equal parts scale, the result will be a straight line, the intercept on the transmission scale being 0.92 and the slope being represented by B.

For illustration, the data calculated in Tables II and IV have been plotted in Figure 1, on semi-log paper. It will be noted that the points fall on straight lines converging to the point representing 92 per cent transmission at zero thickness.

Obviously, if the transmission is known for any one thickness, it may easily be found for any other thickness merely by plotting the known point and drawing a straight line through it and the 0.92 intercept. The transmission for any thickness may now be read directly from the intersection of coordinates at the straight line.

If a great deal of such work is contemplated, a piece of the cross-section paper can be cemented to a piece of plywood, and a ruler mounted on a pin so that it will rotate around the 0.92 intercept as an axis. Such an arrangement greatly facilitates making settings and reading off values, and an entire spectral transmission curve may be transformed to a new thickness in a matter of minutes.

Vaughan[2] has devised a type of slide rule that permits highly accurate conversions between transmission values from 0.1% to 91.5% and for any thickness range. Complete details on the construction of this rule will be published in the near future.

SYMBOLS AND NOMENCLATURE

Unfortunately, there is no standard of nomenclature or of definition of the terms and symbols used in discussing light transmission. Accordingly, comparisons with the work of others in this field will be facilitated if the definitions given below are kept in mind, together with the symbols used.

T = Transmission.	The fraction of incident radiant energy that is transmitted through the specimen.
C = Transmittance.	The fraction of radiant energy transmitted by the first surface that is incident on the second.
V = Transmissivity.	Transmittance per unit thickness.
A = Thickness.	Measured in millimeters for convenience.
R = Reflection Ratio.	Found from the refractive index by Fresnel's formula $\left(\frac{n-1}{n+1}\right)^2$
B = Absorption Coefficient.	Logarithm to base 10 of V, the transmittance per unit thickness.
D = Optical Density.	Logarithm to base 10 of reciprocal of transmission.

The following relations hold:

$C = VA$	$\log C = A \log V$
$T = (1-R)^2C$	$\log \frac{T}{(1-R)^2} = \log C$
$T = (1-R)^2VA$	$\log \frac{T}{(1-R)^2} = A \log V$
$D = \log\left(\frac{1}{T}\right) = -AB - \log (1-R)^2$	$\log \frac{T}{(1-R)^2} = +AB$

[2]Private communication from T. C. Vaughan, of the Laboratories of the Hartford-Empire Company.

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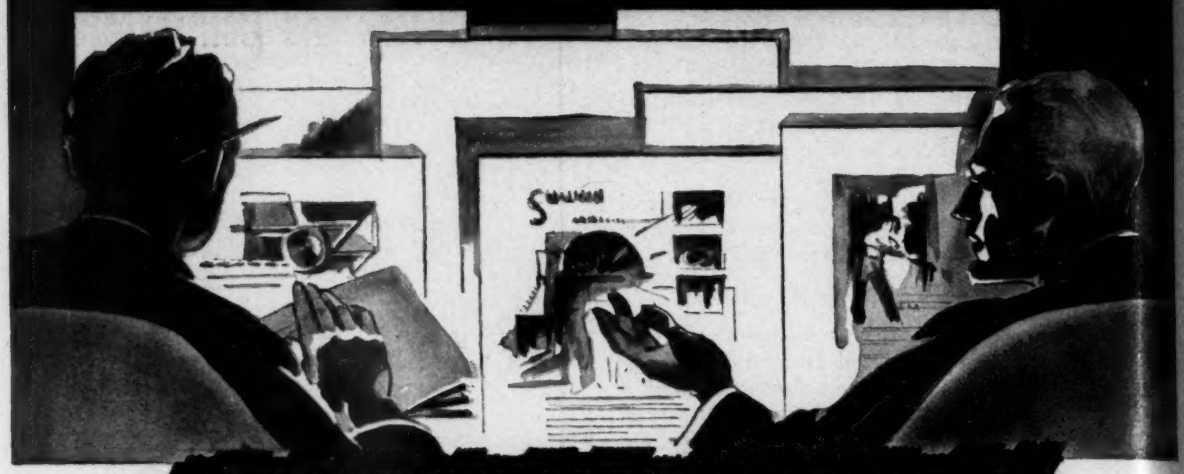

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